Universidade de Aveiro Departamento de Eletrónica, Telecomunicações e Informática
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Joel Eduardo dos Santos Dinis

Sistema de registo de assiduidade com base em smartphone

Attendance control system based on smartphone

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requesitos necessários à obtenção do grau de Mestre em Engenharia Eletrónica e Telecomunicações, realizada sob a orientação científica do Professor Doutor José Alberto Gouveia Fonseca, Professor Associado do Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro.

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Dedico este trabalho aos meus pais.
I dedicate this work to my parents.

o júri / the jury

presidente / president

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Professor Auxiliar do Departamento de Eletrónica, Telecomunicações e Informática da Universidade de Aveiro

vogais / examiners committee

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Palavras-chave Controlo de presenças, plataformas móveis, Android.

Resumo

Os sistemas de registo de assiduidade estão associados à legislação laboral para defender os interesses dos empregados e dos empregadores. O controlo de presenças em escolas adquiriu também extrema importância estando cada vez mais associado ao sucesso académico. Atualmente existe uma panóplia de sistemas deste tipo cujas diferenças estão essencialmente ao nível da tecnologia utilizada como base de funcionamento do sistema.

O mercado de equipamentos móveis apresenta igualmente grande diversidade e um rápido e sustentado crescimento, sendo mesmo um dos mercados com maiores taxas de crescimento ano após ano na área das tecnologias de informação. A venda de *smartphones* representa já mais de metade da venda deste tipo de equipamentos. Devido ás enormes potencialidades dos seus sistemas operativos e do seu hardware, estes equipamentos abriram a possibilidade da sua utilização como parte integrante de um sistema de registo de assiduidade.

Nesta dissertação é proposto um sistema de registo de assiduidade baseado em *smartphone* e em portarias virtuais compostas por dois *Access Point*. O sistema apresenta como principais vantagens o facto de ser barato, a aplicação correr em segundo plano no sistema operativo tornando o processo de picagem um processo automático, e também por ser um dispositivo que o utilizador tem dificuldade em ceder a terceiros, reduzindo por isso tentativas de fraude ao sistema de controlo de assiduidade.

Keywords Attendance control, mobile platforms, Android.

Abstract Attendance control systems are associated with labour legislation for the protection of employees and employers. School attendances' issues may be directly connected to academic achievements at the same time it is difficult to control by children's parents. To solve these problems, there are several systems available and the difference between them is essentially the technology adopted to make them work.

Nowadays, mobile equipment market has a great diversity with smartphone equipments having the highest demands and high growth rates. Due to the huge capacities of their operating systems and hardware, smartphones have now the possibility to be used as part of an attendance control system.

In this dissertation, it is developed an attendance control system based on smarphone and virtual doors composed of two Access Points (APs). This system has the advantage of being inexpensive and, since the application runs in the background of the operating system, attendance detection becomes a fully automatic process. Moreover, since a smartphone is a personal equipment which is hardly shared with other person, attempts to defraud the control system are very unlikely to happen.

Contents

List of Figures

List of Tables

Acronyms

AP Access Point. iv, v, 1, 3, 14, 22, 23, 26, 29, 31, 33, 34, 36–40, 48, 51

APDC Associação Portuguesa para o Desenvolvimento das Comunicações. 18

AS Attendance Samples. 38

BSSID Basic Service Set IDentification. 22, 31

HTTP Hypertext Transfer Protocol. 40

LAN Local Area Network. 21

LBS Location based services. 59

OS Operating system. 3, 18

PDA Personal Digital Assistant. 16

PHP Hypertext Preprocessor. 24

RSSI Received signal strength indicator. 22, 31, 33, 34, 36–38, 50, 52, 53

SQL Structured Query Language. 25

SSID Service Set IDentifier. 14, 22, 29, 31

UI User Interface. 41

WLAN Wireless Local Area Network. 21

Chapter 1

Introduction

1.1 Motivation

According to Oxford dictionaries, attendance is "the action or state of going regularly to or being present at a place or event" while being punctual means "doing something at the agreed or proper time; on time". Nowadays, there are labour laws to protect employers and employees against attendance and punctuality issues and overtime work.

It is very important to manage workplace attendances since the lack of attendance and punctuality can lead to productivity decrease and absenteeism if it becomes frequent. Overtime shifts and excess workload can cause stress, low morale, poor job satisfaction of the employees, leading to an increase of attendance problems. For the company, these issues may represent an increase of financial and administrative costs.

School attendances also emerged as an important factor related with academic success. Along the academic year, students may start to arrive late to school, some of them do not even arrive, and most of the times their parents have no idea about these issues.

Control presences, check in, check out and working time by using paper sheets and security guards or other company staff to note this kind of information, is becoming an outdated way to do it. The company needs someone to be there doing the job and that person needs to be serious so the information noted is nothing but the truth.

As time passes, attendance control has become easier and reliable thanks to the use of electronic devices based on several different technologies. These systems made the control simple, fast and secure but not free of problems. Card reader systems for example, requires employees to always have the card with them at the moment of the control. It is known that forget the card in the car, at home or just at some unknown place happens regularly. Additionally, there is also the possibility to give the card to someone known so that person can make the control instead of the card owner (buddy punching), defrauding the system and, consequently, the employer. Although companies can apply for harsh laws against people who do this, most of the times this is not easily detected. The solution for this problem was to make the control using something not easily shared like the palm of the hand, finger prints, facial recognition, eye recognition, etc..

Smartphones have emerged in the last few years becoming more popular than the traditional mobile phones. In 2013 in Portugal, some market analysts concluded that more smarphones were sold than traditional mobile phones, and the same tendency was verified in other countries. Although a large number of people have at least one private smartphone, an

European study revealed that half of the companies already give their employees access to mobile equipments like notebook PCs or mobile phones with some tariff plan negotiated with mobile operators. In Portugal, that behavior is also being adopted.

The emergence of smartphones, the fact their operating systems are open source, and after an analysis to attendance control systems, their issues, complexity and price, the use of the smartphone to perform the control in a simple, efficient, quick, automatic and cheap way seemed like a good idea.

The attendance control system presented in this dissertation is based on the use of smartphone and two Access Point (AP) equipments representing a virtual door that must be installed in the company or school building. Its *modus operandi* is simple: First, employees/students just need to have the developed application (named as RPAapp) installed and running in their smartphone. Then, when they get near the virtual door, the mobile application will recognize the place and detect if the person is entering or leaving, saving action related information like date, time, virtual door and direction of the movement, to send later to the company/school server when the smartphone has an Internet connection. All of these actions are automatically made, with no need to even hold the smartphone in the hand or have it outside of the pocket (Figure 1.1).

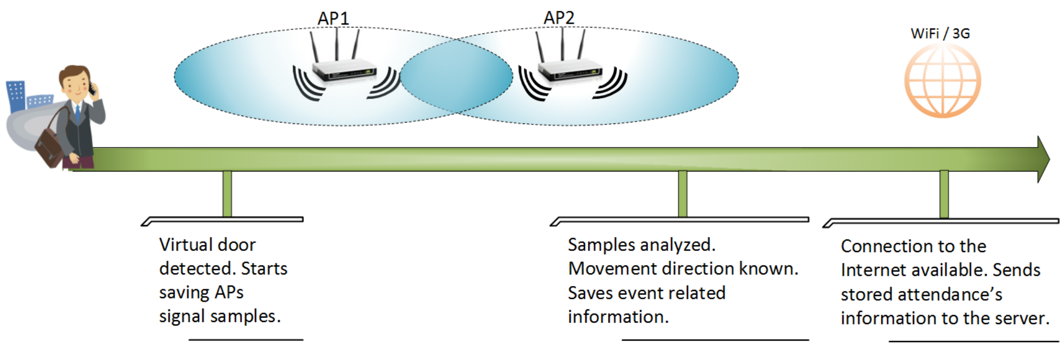


Figure 1.1: Attendance control system *modus operandi*.

1.2 Potential benefits of the system

The potential benefits associated to the use of this system are:

- Reduced costs for the company due to the nonexistence of expensive equipments.
- Fast and easy installation and configuration of the system and smartphone application.
- Automated and fast control processing.
- High level of security allowing better control of work time, punctuality and attendances.
- Employers/teachers/parents and employees/students both have access to this information at any time and everywhere since they have access to the Internet.
- Reduces/eliminates some of the issues found in other systems.
- The system can be installed almost everywhere since electric power is available.

- APs don't need to have an Internet connection and there is no need to collect any acquired control data manually.
- Eliminates the maximum number of users issue that exists in some of the systems referred before.

1.3 Main objectives

The objective of this project is to design a new attendance and punctuality control system based on smartphones running the Android OS, and two APs to create a *virtual door*.

In order to register attendances, a mobile application (named RPAapp) was designed to continuously run on the Operating System (OS) background so the smartphone can detect virtual doors installed on the building and proceed with attendance registration. This event information should then be sent to the server when the smartphone has a connection to the Internet through Wi-Fi or mobile network carriers.

The main objectives are:

- Create a reliable system based on the fact that the employee/student hardly forget or share his/her smartphone with other person.
- Create an automatic system with no need of human intervention after the initial configurations are concluded.
- Must work in buildings with several entrances/exits so, the number of doors should not be a problem.
- The mobile application needs to be configurable since there are in the market different smartphones equipped by different wireless adapters.
- The system should be easily and quickly installed at any place.
- The application should provide employers/teachers/parents access to employees/students attendances and easily inform them about possible absences and/or delays.

1.4 Dissertation structure

This dissertation was written providing all the information needed to allow the reader to understand the context and the concepts involved in this project.

In the present chapter, the motivation for this project was introduced together with the project's main objectives and potencial benefits associated to the use of the system. It is also made an overview of the dissertation structure adopted.

Second chapter exposes several attendance and punctuality control systems available in the market together with their advantages, disadvantages and characteristics.

The third chapter gives an overview of the required hardware devices needed for the project and introduces the Android mobile operating system.

Chapter number 4 is where the development of the attendance control system is explained. It starts by describing the system requirements and architecture, introducing then the developed mobile application main structure. The different stages of the system *modus operandi* are then described and explained being also introduced along those stages, the mobile application algorithm and other features that allow this system to work. The complete project is explained here.

Chapter number 5 has the description and results of several tests made to the system, allowing to draw, in chapter 6, some conclusions about the project and future work to improve it.

Chapter 2

Attendances control systems

2.1 Introduction

Human resources management is becoming more important for the companies year after year. It is important for the employee to know how much time he/she worked and be paid according to that. It is also important for the employer to have access to this information in order to protect the company against extra costs, employee lateness, unauthorized or long breaks and payroll errors.

At schools, miss classes or be late are issues that professors and parents frequently have to face. The absence to school could lead to unsuccessful academic results and to even more absence and delays.

In order to eliminate these issues, several techniques and systems were created and are available to be adopted (Figure 2.1).

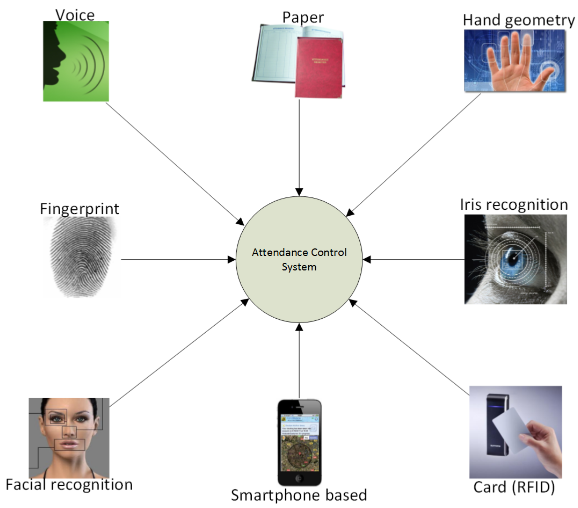


Figure 2.1: Several attendance control systems available.

The first method adopted to control attendances and lateness was to have someone registering this information on paper. This data was then transfered to financial departments were it was analyzed before proceeding with the payments. This archaic way was full of issues.

First, it was necessary to have someone doing the data collection at the entrance, controlling check in, check out, pause times, attendances, etc.. Secondly, that person needed to be paid every month what represented an extra cost for the company. A third issue was the truth of the collected data. This could represent a big problem because, for reasons like friendship for example, this data could be corrupted. Although this is an old way to work, there are lots of enterprises that continue to use this method whether it is because they are small companies and cannot afford more evolved systems, or because they just want to continue adopting this methods. If the last one is the case (and unfortunately it is in some of the situations), the company can easily corrupt this data and their employees have to be exposed to this. Even if it is against the law, there are more cases like this than it can be imagined and most of the times none of the employees make any complaint because they are afraid of the consequences.

The natural evolution to solve this problem was to create electronic devices that were less exposed to errors and corruption, and that were more convenient for the companies and its employees. Over the years this evolution has arrive and lots of different solutions and technologies were developed and adopted for this purpose.

2.2 RFID Attendance Control System

One of the most used time and attendance control systems are based on RFID technology, typically using an RFID card. RFID solutions are composed by three main components: the card (equipped with a tag), the reader (equipped with an antenna) and the host (Figure 2.2). The reader is connected to an antenna that generates a radio signal. The energy generated by the antenna triggers tag's circuit operation sending a signal back to the antenna that is then sent to the host [5]. The host processes the data and stores it so it can be accessed later.

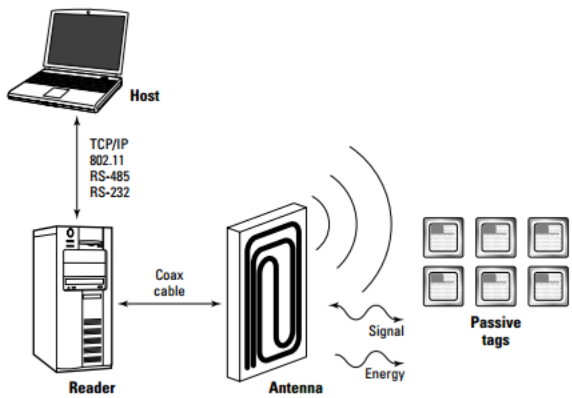


Figure 2.2: RFID system overview.
[5, Source: RFDID for Dummies, 2005]

The system has the ability to uniquely identify and register attendance requiring the employee to just place the RFID card near the reader. It is a simple and very efficient process but it does have some inconveniences. If the building has several different entrances, it will need to have several card readers installed and they all need to be connected to the host, typically through cables which makes it difficult to install. This is also one of the systems were buddy punching is most commonly found. The card holder can easily share his/her card with other person so that person can use it to register the attendance. According to [6] which refers a recent American Payroll Association study, even without committing buddy punching, employees can still steal time by claiming that they forgot to clock in when they got to the place. This can happen because the system is not automated and it requires the user to remember to register the attendance.

2.3 Biometric Attendance Control Systems

The evolution of attendance management systems got some of the RFID reported issues into consideration. Biometric time clock devices appeared in the market to try to eliminate at least the possibility to register attendance without being present.

Biometric analysis is not something new. Fingerprints may be one of the older forms of biometric identifications. They are used for example, to establish identity of documents and at forensic investigation once they are unique to each person.

Nowadays there are different types of approaches in biometrics and not only fingerprints. According to EasyClocking [7] attendance systems manufacturer, there are hand palm geometry, handwriting, face, iris, retina, voice and veins recognition sensors. All this approaches can be found associated to their attendance systems. Because biometric consists in the use of a unique, physical attribute of human body to identify and verify if a person really is who he/she claims to be, they found biometric to be a good market opportunity to reduce or even stop buddy punching. Nonetheless, this could only be achieved thanks to the technology advances, user acceptance, credibility and cost reductions.

The background of these systems is pretty much the same of RFID systems. There is the biometric sensor module to measure or record the biometric data of the user, and there is a host to manage the database. The big difference is that no card will be needed now, just the part of the body that has been registered during the enrollment phase (Figure 2.3). After that, every time the user performs a scan through the scanner, stored scan templates are retrieved from the database and compared to the sample obtained during the scan initially performed. The decision module will identify or reject the identification according to the match score obtained from the matching module. A larger match score indicates greater similarity between the template from the database and the one obtained from the scanner. After the success of the identification process, attendance is registered in the server's database.

Biometric systems are becoming very popular not just for attendance control but also to control the access to buildings, elevators, etc.. However, some disadvantages have been reported through the time like, for example, consecutive scan failures.

The most used biometric attendance control systems will be exposed next.

2.3.1 Fingerprint system

The most common biometric system seems to be the one that uses fingerprint scan technology (Figure 2.3). When this is the adopted technology, to clock in for example, users just need to put their finger in the scanner and wait till a positive identification occurs. During the identification process, the system compares the scanned fingerprint with those stored in the database during the enrollment phase. When successfull identification occurs, the system registers the clock in time.

Although this technology has many benefits, it also has some disadvantages. It's accuracy is not the best. Scan errors frequently occurs when the finger is too dry or dirty, is not placed

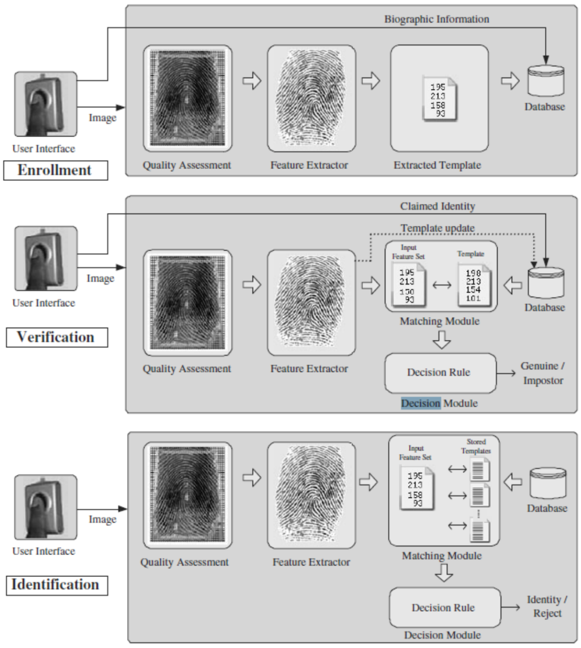


Figure 2.3: Enrollment and recognition (verification and identification) stages of a fingerprint biometric system.

[8, Source: Introduction to Biometrics,2011]

in the correct position or even if it gets injured, i.e., it does not take into consideration the fact that a person can physically change. These issues may cause the system to ask to repeat the scan and most of the times several repetitions are needed, which can be time consuming.

Another important issue is the possibility to hack someone's fingerprint. This is called Spoofing[8] and it is the most known attack to these systems at the user interface level. Get someone's fingerprint may not be too hard to accomplish and several techniques can be found through the Internet.

2.3.2 Hand geometry system

Hand geometry recognition systems are similar to fingerprint's but they use the shape of the human hand to identify the person. This technology is very reliable and can be used in more aggressive conditions, unlike fingerprint equipments, because it scans fingers thickness, length, width, distance between finger joints and hand bone structures (Figure: 2.4).

Although it scans several features, it is not considered an excellent identification system because it does not look for extremely distinctive characteristics during the scan like the fingerprint scanner does. This may lead to errors in the attendances control. Buddy punching can also be a problem in these systems. To prevent against the use of someone's hand mold, some devices require the user to move their fingers and it also measures the hand temperature.

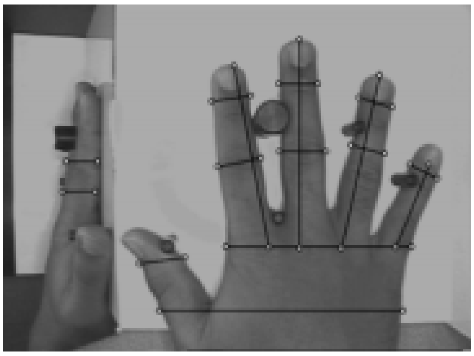


Figure 2.4: Hand characteristics measured by hand geometry systems.
[9, Source: Hand Geometry,2006]

Although these systems are easy to use and are reported as low failure rate systems, they are expensive. If the price is important, this solution may not be the best. They are also hard to use by people with injuries in their hands, like arthritis for example, and it can be considered a dirty system if it is taken into consideration the fact that everyone places their hands in the scan without cleaning them first.

2.3.3 Voice recognition system

The human voice has been studied over the years by scientists and engineers to develop person-to-person and person-to-computer communication systems. Today, there are several applications for digital speech processing. After convert the acoustic waveform to its digital representation, there are different goals that can be achieved through it. Maybe the most important application was the speech coding for digital transmissions to compress the digital message to the lower bit-rate possible.

Text-to-speech and speech-to-text are verifying great developments nowadays thanks to the development of the human-computer interaction. The idea is to communicate with a machine with no keyboard, mouse or movements, just with the voice like two human beings communicating with each other.

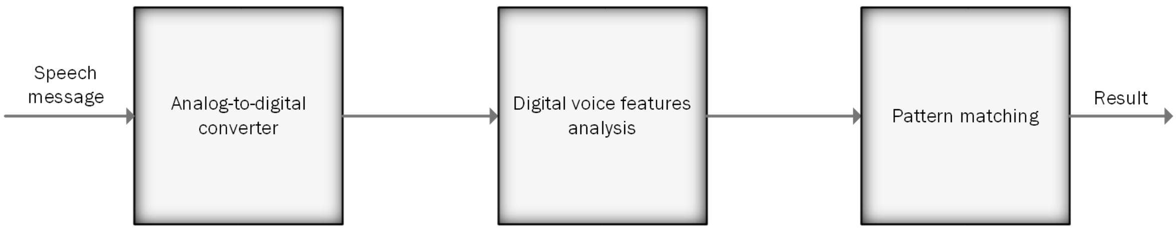


Figure 2.5: Block diagram representing the basic operation mode of a voice recognition system.
[10, Based on the original from: Introduction to Digital Speech Processing, 2007]

Last, but not the least, speech recognition is another large area of digital speech processing. The idea is to extract a message from the captured voice, identify who is speaking and verify the speaker's identity (Figure 2.5). Biometric voice recognition systems follows this idea since the human voice is unique like fingerprints are. The aim is to discover who is speaking, not what is being spoken and, after correct identification of the person speaking, register his/her attendance in the server.

Voice recognition systems analyze several voice characteristics to verify someone's identity. One of the problems of the system is that the human voice may depend of emotional factors (a person state of mind for example) and of the health of the person (if he/she has sick throat,etc.). In addition to this problem, external factors like other people talking or other environment noises, can compromise these systems' efficiency.

2.3.4 Facial recognition system

"The face is considered to be the most commonly used biometric trait by humans; we recognize each other and, in many cases, establish our identities based on faces. Hence, it has become a standard practice to incorporate face photographs in various tokens of authentication such as ID cards, passports, and drivers licenses"[8].

Following the idea of the previous paragraph sentence, if human beings can distinguish between each others through the face, a natural evolution was to try to make machines to recognize a human through the same method. The concept of *face recognition* was then created.

The same authors describe *face recognition* as "the process of establishing a person identity based on their facial characteristics.". These characteristics are called nodal points and can be the overall facial structure, distance between the eyes, forehead, mouth, nose, the length of the jaw line, etc..

After more than 20 years of research in the area [11], the technology is now developed enough to be used in military, homeland security, criminal investigations, law enforcement, access control, time attendance, etc..

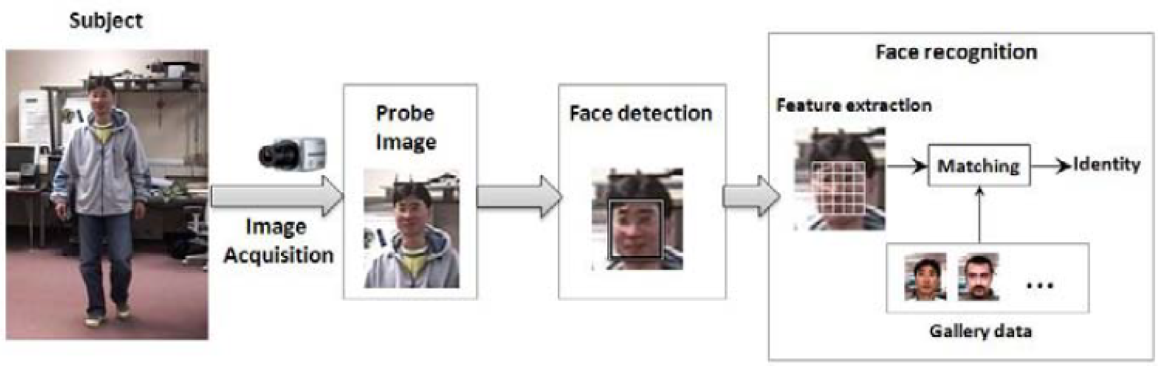


Figure 2.6: The three basic modules of a face recognition system.
[8, Source: Introduction to Biometrics,2011]

The basic attendance system using this technology consists in three modules: image acquisition, face detection and finally, face matching. To do this, machines equipped with a camera are needed to acquire the image. The nodal points are measured after the face detection, and a faceprint is then created and compared to the ones present in the database. If the system can find a similar faceprint in the database, it registers that person's attendance on the server (Figure: 2.6). Like other systems referred before, there are some factors that can cause errors during the face recognition process:

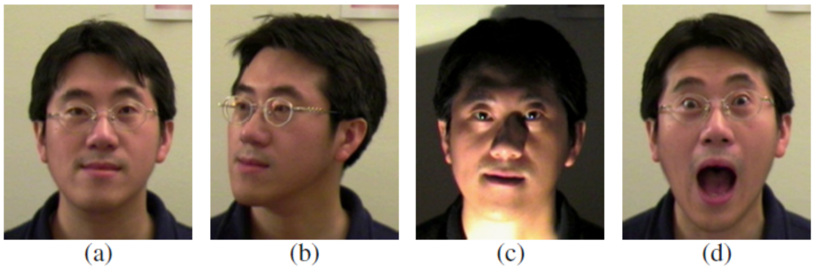


Figure 2.7: Variety of changes that can make automated face recognition a challenging task. Frontal face image (a), pose (b), illumination(c) and face expression (d) problems.
[8, Source: Introduction to Biometrics,2011]

- Lighting change affects the recognition of the face [12]. A comparison between the face image 2.7(a) with 2.7(c) where lighting has change, gives an idea of how much the recognition can become harder or even impossible in these conditions.
- Movement and pose during image capture can lead to extreme difficulties in the face recognition process 2.7(b).
- Aging factor, beard, eye browns, etc., change the aspect of a person.
- Face wearing accessories like glasses, piercings, earrings, hats, etc.
- Mental state of the person can lead to several different face expressions 2.7(d).
- All the previous aspects can make the face recognition process slow if the person needs to adjust their position in front of the camera or make the same expression that he did the first time he registered his face in the database, etc..
- Equipment cost can become too expensive to support if several devices are needed to be installed in different doors and buildings.

2.3.5 Iris recognition system

TimeWellScheduled [13] is a company dedicated to time and attendance control. According to them, iris based systems are harder to find for that purpose, nonetheless, they exist and can be used.

The operation mode of these systems is similar to other biometric systems but they use a camera to capture an image of the eye iris pattern. The image is then processed and a pattern is generated to be compared with images previously recorded in the database, in order to find out the user identification and proceed with the attendance registration (Figure: 2.8).

Because the eye is one of the most protected organs of the human body and its characteristics are stable and fixed during almost all life time, this system is one of the most secure systems, especially for access control. Unlike facial recognition for example, this system's accuracy is not affected by the use of glasses or contact lens. In terms of performance, they have the lowest error rates and in terms of speed they usually need between one to three seconds to perform the identification[14] depending on the device and the size of the database.

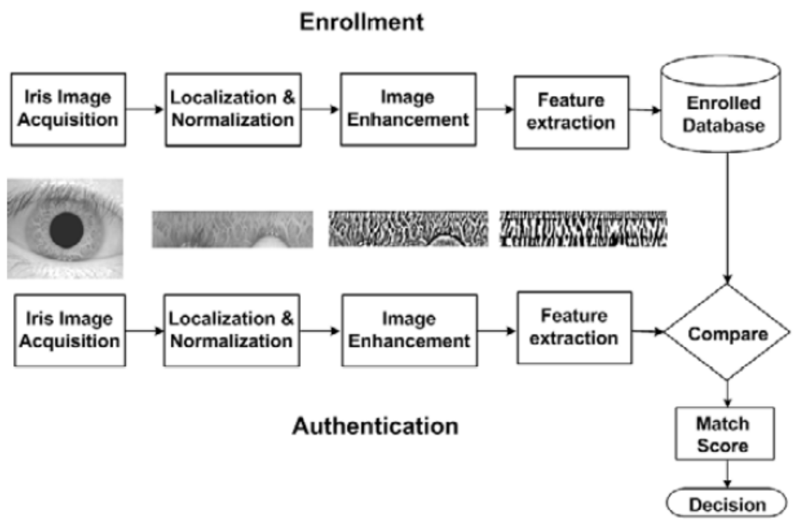


Figure 2.8: Block diagram of an iris recognition system.
[8, Source: Introduction to Biometrics,2011]

All the attendance control systems referred along this chapter can be too expensive for some of the companies that want to adopt an attendance system. Furthermore, they may need to be directly connected to a server to register the attendance and control the amount of time that each person works. If a civil construction company for example, wants to control time and attendance, they can do it the old way (paper), or there can be the possibility to use one of the systems presented along this chapter. Nonetheless, they will require the data to be collected manually from the scanners if they are not connected to a remote server. Install equipments like these in temporary work places may also be problematic due to their cost and difficult installation. In order to simplify such situations, the emergence of mobile phones and smartphones allowed to face time and attendance control in a different way.

2.4 Mobile phone and smartphone based attendance systems

Nowadays, it is possible to find some mobile phone based attendance systems with different operation modes but all with the same final purpose: know exactly when and where an employee registered an attendance.

When typical mobile phones emerged, some companies started to focus their attentions in the creation of attendance systems based on these new equipments. Freedom Telecare [15] has developed simple but innovative solutions in this area like TimeSheet Mobile solution (Figure 2.9). When using this solution, employees were able to use a mobile phone (didn't need to be a smartphone) to clock in/out from company buildings or temporary job sites for example. In order to do that, employee just needed to call to a specified telephone number and enter his/her identification number. The time of the action was then registered on the system.

Nonetheless, with smartphones growth, these technologies started to be left behind. With a smartphone, it makes no sense that employees have to loose time calling to any phone number and enter their information. Even Freedom Telecare immediately created a mobile

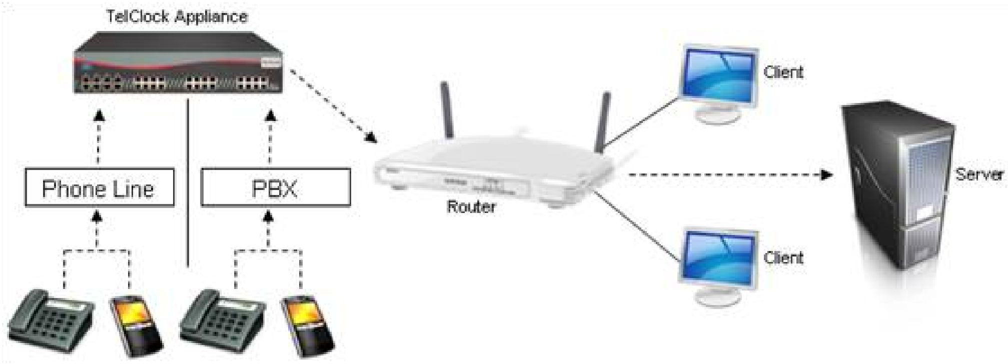


Figure 2.9: Telclock[1] ilustrative diagram. Telclock is an attendance system from Data Management, Inc. that is similar to the TimeSheet Mobile solution.
[1, Source: TimerClock Plus website,2014]

application in order to ease the process of the TimeSheet Mobile solution.

Bodet [16] is another company that has been working in the attendance control area since 1860s. Over the years, they have developed several different equipments using some of the technologies already mentioned along this chapter. Currently, they provide an attendance smartphone clocking in/out solution named *Kelio Mobile Intranet*. This mobile application allows users to clock in/out through their smartphones pressing a simple button on the screen. When the user taps the screen, time and gps position are sent wirelessly over the Internet to a server that processes that information. This enables the employee to declare and control working hours and punctuality at the same time it allows the employer to have instant access to the data. This solution can be used everywhere. Nonetheless, it was projected to help those companies with their employees on the field, moving from place to place, outside the company's buildings.

Another companies appeared in the market with similar solutions to *Kelio Mobile Intranet* but with some add-ons. ExactTime [17], for example, has the particularity of being able to eliminate buddy punching through the use of the device's front camera to get a photo of the employee, allowing identity verification by the system.

Some similar projects started to be developed to apply in students attendance control. In the proposed solution by [18], students need to log in to the smartphone application and get connected to the server. After logging in, they will register attendance and the data will then be sent to the server through GPRS. If their location is not the correct location, students are unable to register their attendance in the class.

There is also a project using bluetooth technology [19]. It consists in the detection of students' mobile phone bluetooth to declare their presence in the class. The detection of their bluetooth module is made by another bluetooth module placed inside the classroom. This receptor will be responsible for constantly scan and detect students' mobile phone and send their identification to the server that is responsible for the data management. It seems to be a simple solution and it can be used with regular mobile phones, it doesn't need to be a smartphone. Nonetheless, it has some disadvantages like, for example, the bluetooth range (approximately 10 meters) which makes it hard to apply to large company buildings.

All the systems referred along this chapter are used to control attendances at schools or enterprises. Besides the disadvantages referred before, they have some disadvantages in common. For example, in a building with several doors, have a biometric or RFID scanner at each door entrance may be to expensive to support, and there is always the need to have them all connected to the server through cable or, if possible, wirelessly. There is also the delay that some of those systems can verify due to errors occurred during scans, which can cause some waiting queues.

Control attendances in a temporary job site where there is no connection to the network to send registered data to the server, or the simple fact that none of these systems are fully automated (they all require user intervention) are also issues that can be solved by the attendance system that will be presented later on this document.

To face these problems, there is a registered patent [20] which intends to improve attendance systems using a smartphone and Wi-Fi signals. The main objectives are basically the same as the system described in this project: be simple, low cost and automatic. Although it looks very similar to the one proposed in this dissertation, there are some important characteristics that distinguish both of the systems.

According to [20], the Service Set IDentifier (SSID) of a Wi-Fi signal source in the area where the employee is located, is collected by the smartphone. This information is then sent to the server and compared with the stored information. If the employee is where it should be, attendance is registered by the server. This means that the employee must be all the time inside the cover zone of that Wi-Fi signal source, otherwise clock out is registered. It is true that both of the systems have in common the use of smartphone and Wi-Fi signals to detect an attendance event. Nonetheless, they are used in a very different way once the proposed attendance system uses APs devices to create a virtual door at the entrance of the building allowing the employee to move freely inside it.

Chapter 3

Overview of the required hardware and software

3.1 Summary

In this chapter, it is made an introduction to smartphones and Android operating system, giving an idea of why a system like this is now possible to achieve. Access Points are also introduced since they are a very important part of the developed system.

3.2 Smartphones

It all started on April 3, 1973, in New York City by the voice of Martin Cooper (general manager of Motorola's communications Systems Division at the time). The first public telephone call placed using a portable cellular phone while "walking down the street (...) using a 30-ounce phone" was made by him [21]. Before that, there weren't cordless phones and almost nobody could imagine that one day they could exist and become more important than those fixed phones. Nonetheless, Martin Cooper and others from Motorola had a different picture of the future as he himself says:

> The time was the late 1960s. There was one telephone company in the US, one in Britain and one in Japan and so forth. In our case it was AT&T and they were the largest company in the world and they had invented this thing called cellular. Their invention was car telephones. Can you imagine? We believed people didn't want to talk to cars and that people wanted to talk to other people and the only way we at Motorola, this little company, could prove this to the world was to actually show we could build a cellular telephone, a personal telephone. Something that would represent an individual so you could assign a number not to a place, not to a desk, not to a home but to a person. **??**

After ten years, the first commercial portable cellular phone was launched in the market. The model was the Motorola DynaTAC weighing 794 gram and with a cost of almost 4000 USD[22]. The way people communicate was gradually starting to change and it became irreversible. After this phone, hundreds of different mobile phones were launched by different companies like Nokia, Samsung, Sony Ericsson, Panasonic, BlackBerry, HTC, LG and Apple (Figure 3.1).

It is possible to see in Figure 3.1 the evolution of the design, size and even technology of the phones. They started by being large phones with small black and white screens but the tendency was to become smaller in body and with bigger and colored screens. Since the introduction of touch screens in mobile phones, the tendency was to become thinner and bigger again.

But not just the size, appearance and screen technologies have changed. During this time period, lots of other changes were made in the mobile phones area. The evolution from 1G to 2G, later for 3G and now for 4G, allowed phones to be more than a solution just for calls and text messages. At the same time they started to have more hardware like GPS sensors, wireless adapter, bluetooth, storage expansion capability, accelerometer, powerful processors, etc., they also started to have simplified access to the Internet via their network operator or Wi-Fi. At this time mobile phones started to become "smarter".

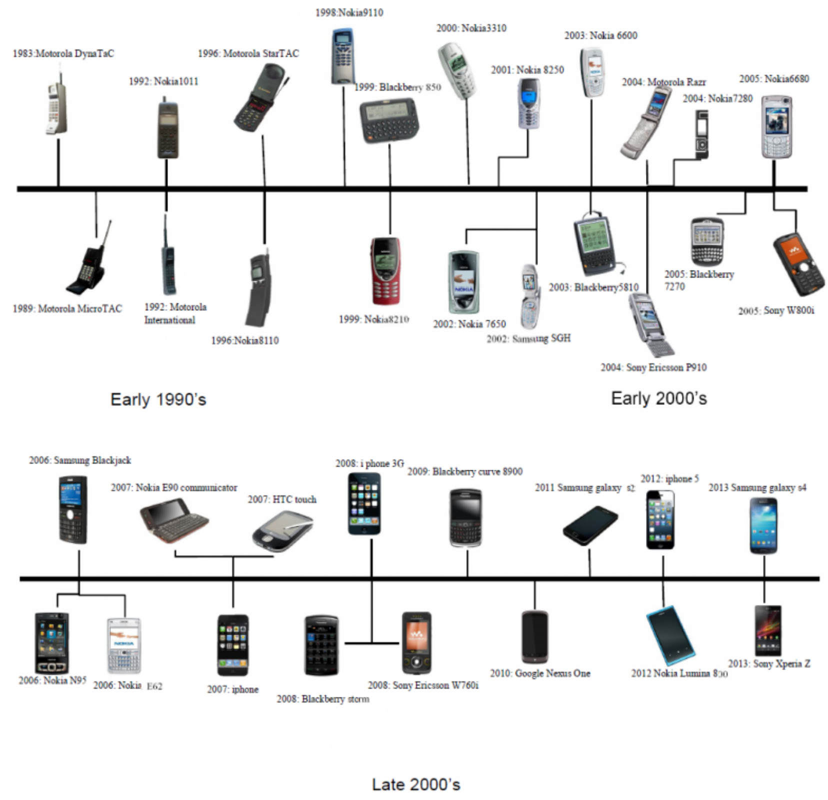


Figure 3.1: Mobile Phone's evolution timeline.
[23, Source: Engineers Forum magazine]

Manufacturers started to develop some games like Tetris and Snake and small applications for their terminals adding later the ability to play music, take pictures and make small movies. Nonetheless, because manufacturers didn't want to reveal the secrets of their phones, probably due to the competition between them, all the software developed for the phones was developed only by themselves.

That behavior has started to change when Personal Digital Assistants (PDAs), running operating systems like Windows for example, came to the market. Manufacturers started to expose their hardware design to the world and several mobile platforms started to be created. Palm OS, Symbian OS, iOS, Android and Windows Phone are some of the most popular operating systems for mobile devices. The adoption of these platforms as phones' operating system, allowed developers from all around the globe to be able to develop software not just for one phone from a particular manufacturer but for several different phones from different manufacturers. Together with the growing hardware capabilities, developers could start developing different applications for different purposes and the mobile application market started to make millions of profit.

According to a market analysis made by IDC to the Jornal Público in Portugal, the year 2013 was the first year where more smartphones were sold then traditional phones (Figure 3.2) and now the estimations are that, more than 3.5 million persons in Portugal uses a smartphone [24].

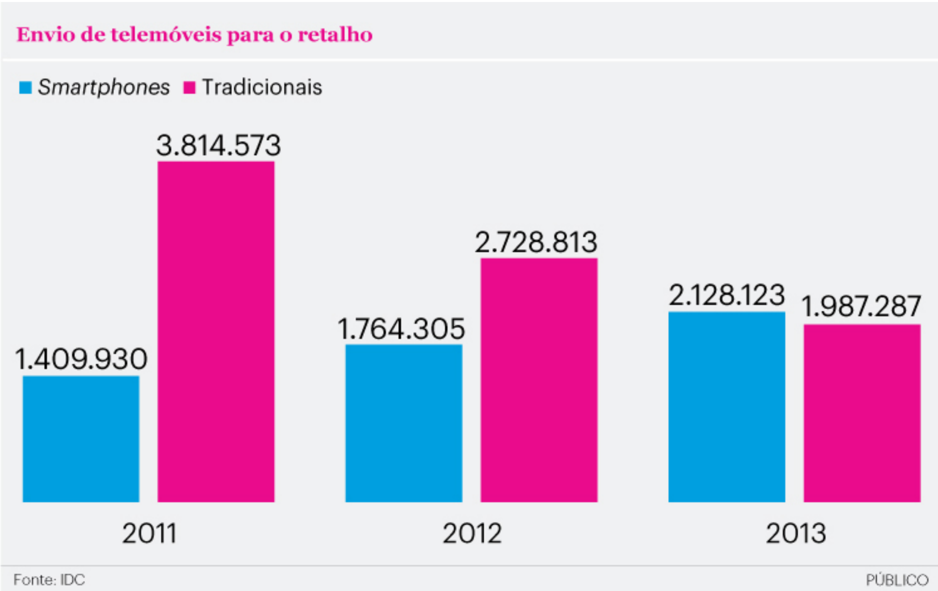


Figure 3.2: Smartphones and traditional phones sold in Portugal.
[25, Source: IDC/Público]

Like Martin Cooper predicted, phones became an irreplaceable part of the human lives. This became so true that Ian Carrington, a mobile and social advertising sales director at Google, said during a speech that "There are now more people on earth that have access to a mobile phone, than have access to a toothbrush".

In a moment were people are used to be always with the smartphone in the pocket or in their hands (it is hardly forgotten at home or borrowed to someone else), it makes all the sense to use it as a low cost attendance control system. But what are the reasons that allow to do that now with smartphones and not with traditional mobile phones in the past? Besides their hardware capabilities like wireless adapter, better processors and access to the network, the main reason is the operating systems created and adopted nowadays.

3.3 Operating systems

3.3.1 Introduction

As mentioned in the previous section, when mobile phones started to become "smarter", it was hard to develop applications because their mobile operating systems were private and made by each manufacturer. At that time, if a mobile phone-based attendance control system was needed, each manufacturer would need to be responsible for the development of the app for each of their terminals. Of course this was something impossible to think about because, something like this, wouldn't be low cost or so easy to build for sure.

Later, mobile operating systems started to be designed to run on mobile devices like smartphones or tablet PCs. This standardization of mobile OS made possible the creation of different devices from different hardware manufacturers but running the same operating system. It allowed users to have a similar experience even using different terminals.

Each hardware manufacturer started to design their phones to the chosen mobile OS. Once the OS is the one who manages all the hardware of the device and is the responsible for the connection between the software and the hardware, it became possible to create software to all the devices using the same mobile OS, without having to worry about the hardware design of each terminal. It means that it is now possible to design, for example, an Android OS application that makes use of the GPS sensor, to run on several different equipments from different hardware manufacturers. If all the equipments are running Android OS, and all have a GPS sensor, it doesn't mater the manufacturer of the equipment because they all be able to run the application, except if it was not designed to run on certain versions of the OS.

The mobile operating system chosen to be the base of the system developed and presented in this dissertation, was the Android OS. Others could have been chosen like iOS from Apple or Windows Phone from Microsoft. Once Android is the one, according to Associação Portuguesa para o Desenvolvimento das Comunicações (APDC), with the higher market share (almost 79%) [26], it makes sense to start developing for Android OS devices once the probability of one person to have an Android equipped device is greater. Nonetheless, Android was chosen for this work just because of the available equipment at the moment. Therefore, from now on, the focus will be only in the Android OS.

3.3.2 Android Operating System

The Android OS is an open source platform especially designed for mobile devices. It is cross-compatible[27], that is, it is not only designed for smartphone use but also for tablet PCs, televisions, wearable devices, cars and even laptop PCs too. It became known when Google purchased Android,Inc in 2005 [28]. Until that moment not much was known about Android. To "accelerate innovation in mobile and offer consumers a richer, less expensive, and better mobile experience", a consortium of technology companies (manufacturers, software companies, mobile operators, etc.) was created originating the Open Handset Alliance [29].

For being an open platform, Android allowed any hardware manufacturers to make or sell Android equipped devices. Of course this had a consequence: quickly gain market share. But the market share doesn't come alone with the fact of being an open platform. Being a comprehensive platform, which means it is a complete software stack for a mobile device, helped to make Android what it is today. Most of the stack, from low-level native, Dalvik virtual machine, application framework and even standard applications, is completely open for developers and manufacturers and allows them to work independently.

For developers, Android allows the access to the entire platform source code so they can see how the entire operating system works. It also allows them to change it without needing to have a license for it. There are only a couple of low-level pieces of code that are property of each vendor[29].

Android can be divided in five primary pieces: applications, application frameworks, native libraries, Android runtime, and the Linux Kernel (Figure 3.3).

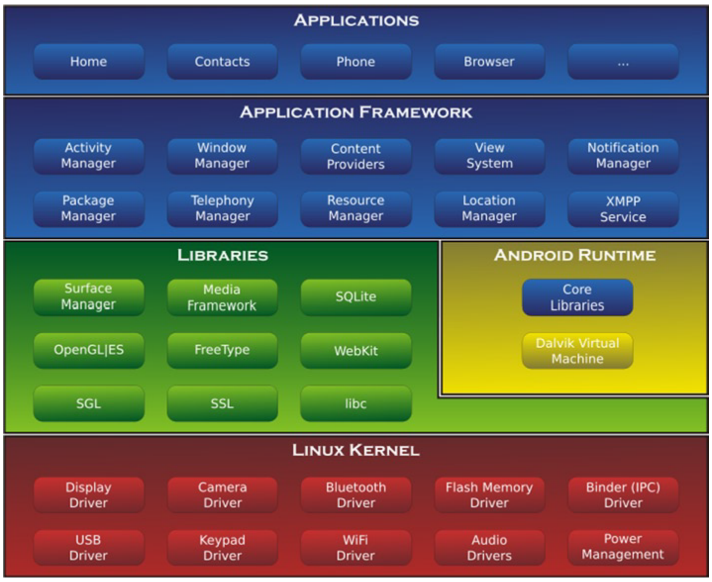


Figure 3.3: Android architecture stack
[28, Source: Android on x86, pp:3]

Android creators decided to built the operating system over a Linux kernel, adding their own middleware, libraries and APIs to the kernel creating the Android Framework[30]. The main reason to choose this Kernel was the fact of Linux be a great operating system and the prototype of open source, security and portability [29]. The Linux kernel is where all the hardware drivers are. It is responsible for the communication with that hardware, it acts like an abstraction layer between the hardware and the software.

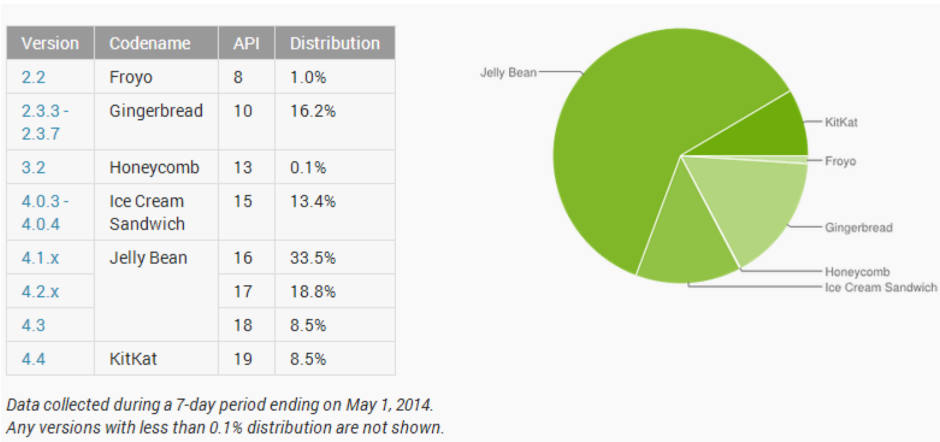
Above the *Linux kernel* layer is the *Libraries* layer. Here is where a set of the most important native libraries are. Media libraries to play and record audio and video, SSL libraries responsible for internet security, OpenGL libraries used to render 2D and 3D graphics on the screen, are examples of the content of this layer. These native libraries are C/C++ libraries and their main function is to support the *Application Framework* layer, providing the instructions to allow the device handling different types of data [29].

Because developers mainly build their applications using the Java programming language, in the same layer of the *Libraries* layer, is the *Android Runtime* layer that includes a set of core Java libraries. It also includes the Dalvik Virtual Machine, who is responsible for running all the applications installed on Android devices. The idea is to have a device running multiple virtual machines once each application gets its own instance of the Dalvik virtual machine [29]. One of the reasons to create the Dalvik virtual machines instead of use Java virtual machine was the licensing once the last one is not free for use.

The *Application Framework* is the layer that contains and provides Java libraries specifically built for Android and also the standard Java libraries to help the application developer when creating an application. It provides many services (or managers) representing the capabilities the application can have, such as WiFi, GPS sensors, etc. [28][29]. This stack layer is the one who catches most of the attention from the developers along the development of the application.

The *Applications* layer in the highest level, is supported by all the other layers of the stack and is the one everyone is familiar with. Every Android user has contact with this layer once it is the support to all the applications installed in the smartphone. These applications are primarily written in Java language and can be obtained from the Google Play Store or installed via USB for example, if the user has the APK file for installation.

Although the *Applications* layer is where the installed applications are, it doesn't mean that all the applications designed for Android-based devices are eligible to work in every smartphone. It is required to the application to adapt to several different devices once there are variations between them, starting from the screen size, languages and also Android platform versions.



Version	Codename	API	Distribution
2.2	Froyo	8	1.0%
2.3.3 - 2.3.7	Gingerbread	10	16.2%
3.2	Honeycomb	13	0.1%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	13.4%
4.1.x	Jelly Bean	16	33.5%
4.2.x		17	18.8%
4.3		18	8.5%
4.4	KitKat	19	8.5%

Data collected during a 7-day period ending on May 1, 2014.
Any versions with less than 0.1% distribution are not shown.

Figure 3.4: Android platform versions
[31, Source: Android developers website]

Once Android is in continuous development, from time to time new releases are launched [31]. New versions of Android have the ability to run applications designed for older versions of the OS. Although, it is possible that new applications do not run on older versions of the Android OS. It will always depend of what minimum API target the developer established for the application.

The RPAapp developed for this project was designed to reach the largest number of users so, acording to Figure 3.4, it made sense to develop for Android versions starting on Android Eclair released on October 26,2009 (API 7)[28]. This way, it was guaranteed that all the Android smartphones released after that date and running any version launched after that moment, are eligible to run the application.

3.4 Access Point

After a brief introduction to the smartphone and the selected operating system, there is one last hardware equipment to introduce before proceed to the attendance system analysis.

This hardware equipment is the Access Point and it will allow the smartphone to detect where the door is and the direction of the movement (entering or leaving).

Since the beginning, communications between devices needed to be done by connecting wires between them (creating what is called as Local Area Network (LAN)). In 1970s, Ethernet was introduced as a new method to connect multiple computers and it became the most used type of LAN connection protocol. Nonetheless, mobility started to become a needed evolution and Wi-Fi (also known as IEEE 802.11) was then created. The use of Wi-Fi technology made possible to abandon, in some situations, the use of wires for the communications between computers of the LANs, replacing them with radio signals. Cables through the walls to connect every device of the network started to fall into disuse since Wireless Local Area Networks (WLANs) became a possibility. They are now substituted by a device called Access Point.

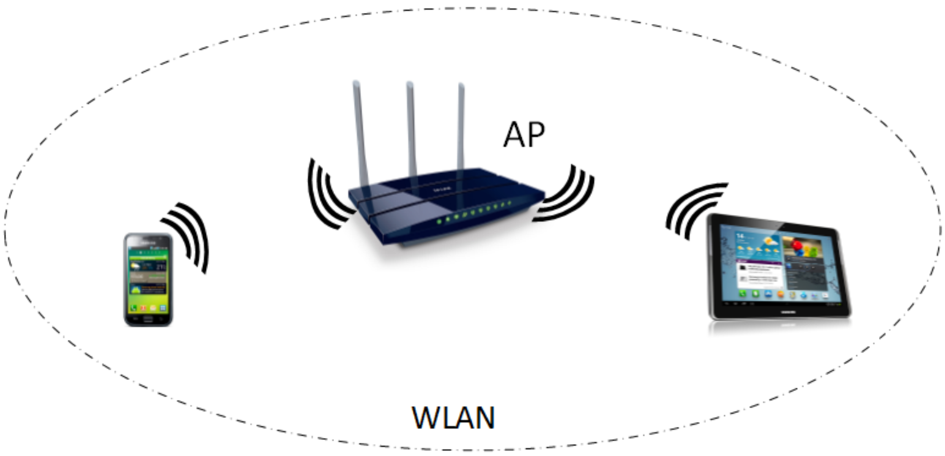


Figure 3.5: WLAN created by an access point device. Images' sources:[2, 3, 4]

Figure 3.5 shows two devices in the same network communicating through radio waves. Each device sends the data through the wireless medium to the access point and that data can then be sent to another devices in the same network. It also has the ability to behave as a bridge between the wireless and wired, which made these devices to became very popular and used in almost every house or office that pretends to have a local area network. Usually the devices for home use are low-cost because they lack several features, but they have just enough features to be used in the purposed attendance system since they don't consume too much electrical power and they are not very expensive.

To cover the distance around, the AP uses omni-directional antennas to provide equal signal strength in all directions. Nonetheless, one characteristic that may be an inconvenience is the cover distance of the AP. The promised maximum distance usually represents the maximum distance in a field free of obstacles. Once there are walls, doors, furniture, etc., this distance is always less than the announced distance. To fight against weak signal power in some dead spots or to focus its output power only on a specific zone, there is always the possibility to use a directional antenna.

Once the communications are made through radio waves, Wi-Fi has a reserved band of the radio spectrum around 2.4GHz for 802.11b, 802.11g and 802.11n protocols, and around 5.2GHz for 802.11a protocol. The band is then divided in several channels (14 in total) used to make the connections. Nonetheless, the number of Wi-Fi radio channels used depends of the country. In Portugal, like the most of the Europe, thirteen channels are available[32].

After establishing a link with a device, the AP sends and receives data through the referred channels. However, to create this link, these channels are used not to send data to a specific device but to broadcast a frame called beacon, which enables near Wi-Fi equipments to know there is an access point in the area. These beacons are sent through every channel within a beacon interval time. When a Wi-Fi equipped device wants to connect to an access point, if it performs passive scans (like smartphones do), they will search each and every channel for a period of time, trying to listen to these beacons announcing an access point in the range. After performing a passive scan, the device has important information about the access point like their SSID, Basic Service Set IDentification (BSSID) and AP Received signal strength indicator (RSSI).

Chapter 4

Development of the attendance control system

4.1 Summary

In chapter 2 it was given an overview of some attendance control systems, some are still available in the market, others already deprecated and finally, some are being developed right now and may be implemented in a near future.

Next, in chapter 3, the hardware equipment used for this dissertation project was introduced together with some of their history and main functions to better understand the implementation of the system and the role of each hardware device. The Android OS was also introduced.

The current chapter aims to describe all the development made to achieve the final version of the attendance control system. System configuration, data acquisition and data processing (application and server side) will all be explained next.

4.2 System requirements and architecture analysis

As previously mentioned in chapter 1, the main objective was to develop a system capable of automatically control the attendance and punctuality of employees or students using just the smartphone as the clock in/out tool and requiring no intervention from the user. At the same time, it should be easy to install and the mobile application should be configurable so it works in the majority of the Android smartphones independently of the hardware they are equipped with. Because it may exist more than one entrance to the building, the system must have no limitation related to the number of doors.

A server is also needed so the developed application is able to send the data to a database to be available later for analysis by the employer (if installed in an enterprise) or by the parents or professors of students (if installed in a school). Regardless of their location, if they have access to the Internet they should be able to access to this information through the smartphone.

In terms of hardware, to have this system working, two access points are needed together with a smartphone with RPAapp installed. The APs don't need any access to the Internet, they just need to be switched on, installed in the right place and have also the wireless adapter switched on.

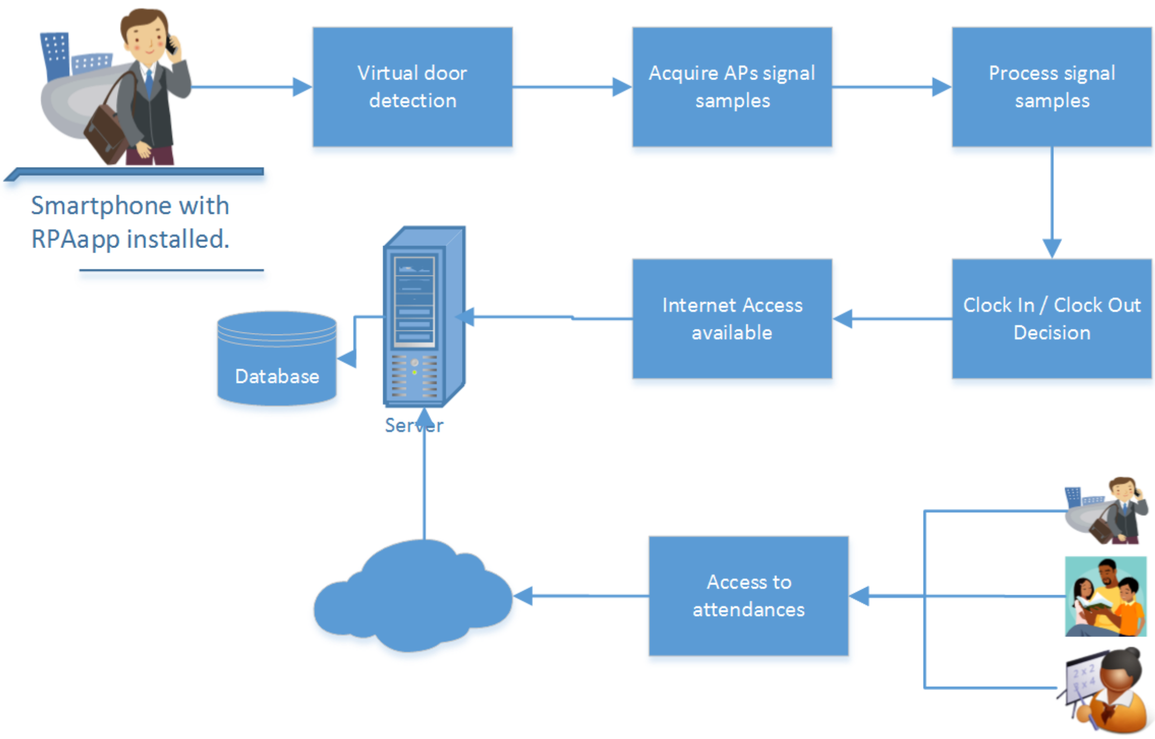


Figure 4.1: RPAapp's different phases until an attendance is registered or accessed.

Figure 4.1 introduces the system's main function divided in a series of different blocks that will allow to achieve the desired results. Each of the blocks were developed for this project and will be explained throughout this chapter in the respective subsections, starting with the block representing the server.

It should also be referred that, during the execution of this project, security issues were not taken into consideration. It means that the final result will not be protected against some sort of attacks that may occur.

4.2.1 Server and database

For an attendance control system, there is always the need to store diverse information. In this project, information like the user name, id and smartphone's MAC address must be saved in order to identify a person. When an attendance is registered, information like the date, time, movement direction and the door where it occurred needs to be saved so it can be accessed later.

In order to know if the user registered his/her attendance on-time, each user's work schedule must also be known by the application. Therefore, it is clear that there must be a server online and available without interruption regardless the time or day of the week. Once this was hard to have due to the hardware needed and the associated costs, another solution was arranged for the purpose of this project: free web hosting provider [33]. Using this web service, it became possible to have a server 24/7 online. Of course the service offered by the provider is limited, for example, in terms of bandwidth and store space, but nothing that could affect the execution of the project.

The purpose of the server is to save the data sent by the application. For that to became

Table: person

name	id	device's MAC Address
...	...	...

Table: attendances

inOut	date	time	door	device's MAC Address
...	...	...	...	...

Table: schedule

in1	out1	in2	out2	device's MAC Address
...	...	...	...	...

Table 4.1: Database tables where the server saves data.

possible, a web service was developed using Hypertext Preprocessor (PHP) programming language to make the bridge between the Android mobile application and the database stored in the server. The database is composed by three different tables to save the three different types of data that can be sent to the server: person information (person table), working schedule (schedule table) and finally, attendances (attendances table) (Table 4.1).

The database is a MySQL database developed using Structured Query Language (SQL) programming language and it is hosted by the server. Every time the Android application needs to send or get data from the database, it communicates with the server sending the respective request. The server inserts or gets the requested data and sends back to the smartphone a message containing the data or a *success* message. By doing this, the data is always available to all the registered RPAapp's users and most of the computational hard work is done by the server and not by the smartphone.

The database is accessed in the following situations:

- Insert new person's information in the database.
- Find out if a specific user is already registered.
- Get all the registered users.
- Insert attendance's data.
- Get all the registered attendances associated to a specific user.
- Get person's work schedule.
- Update information of a specific user like his/her ID, for example.

The context of each situation listed above will be introduced along the presentation of the mobile application.

4.2.2 Virtual doors

In order to have the system working and be able to clock in/out automatically, with no intervention from the user, the smartphone needs to have access to some kind of data that can be processed, allowing then to decide if the user is entering or leaving the building. For this project, this data is the radio waves' power strength transmitted by the APs that composes a virtual door. It is called a virtual door because there is no need to have any physical door installed, it is just necessary to have two APs installed in the area where persons use to cross when they are leaving or entering the building.

The virtual door can be created in different ways but always using those two access point devices. In order to detect the user's movement direction, smartphone detects the networks created by those APs and analyzes their signal strength. Without extending this subject right now, once it will be explained with detail later on this chapter, the signal strength variations will make it possible to detect the movement direction.

But why two APs devices? It is simple. If there was just one reference point, it will be possible to know when the user was getting closer to it, but it wont be possible to know from what side he/she was getting closer. In a scenario where the reference point is only one access point, the idea is the same. The introduction of a second access point will allow to have a second reference point, making possible to know the direction of the movement: from AP number 1 (AP1) to AP number 2 (AP2) or vice-versa.

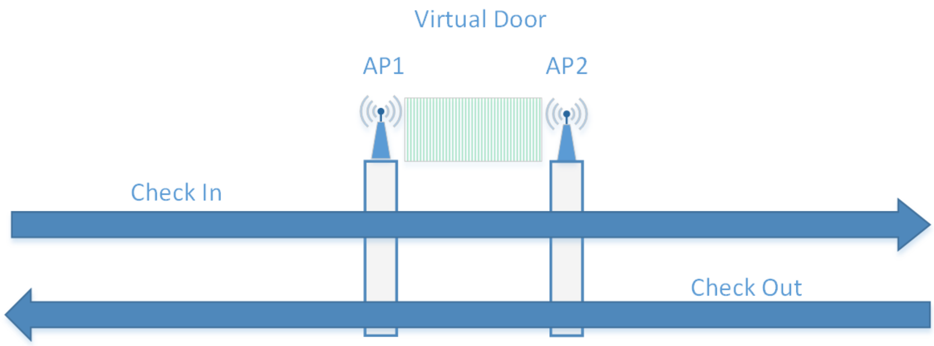


Figure 4.2: Virtual door's configuration.

Figure 4.2 helps to understand the concept of virtual door. There are two APs and the green zone between them that must be an attenuating material, like a wall for example, or a distance large enough so the signals' strength received by the smartphone are as different as possible allowing the algorithm that decides the movement direction to work. After the installation of the APs and configuration of the smartphone, the user just needs to move through the zone covered by both APs while the RPAapp automatically detects the movement direction.

From now on, like represented in Figure 4.2, it is assumed that, when a person is clocking in, the first access point of the virtual door is the access point *AP1*. It is also assumed that the first access point of the virtual door when clocking out is the *AP2*. This will be important to understand the *modus operandi* of the system later on.

4.2.3 Introduction to the developed mobile application

Before analyzing the blocks of the sequence shown in Figure 4.1, an introduction to the developed application must be done once it will be responsible for the APs' signal samples acquisition, to allow attendances to be detected and registered.

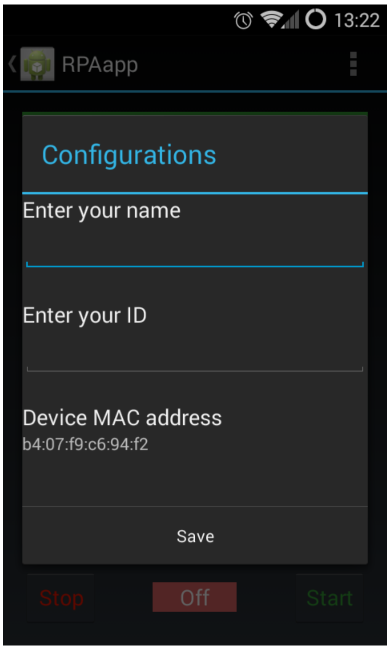


Figure 4.3: First run application screen.

Figure 4.3 shows the user interface of the application when it runs for the first time. At that moment, the user is asked to enter his/her name and the associated id at the same time the smartphone's wireless adapter MAC address is obtained and shown on the screen. When the *SAVE* button is pressed the user must have an Internet connection so the application can communicate with the server.

The following actions are performed by the application when the *SAVE* button is pressed:

- Verifies if the server can be reached. If not, asks the user to connect to the Internet first.
- Sends person's information to the server.
- The server searches in the database if the user already exists. If exists, updates his/her information, if he/she doesn't exist, stores the data in the database.
- The server sends back to the mobile application a message containing a success flag and the action made (update or insert new person).

If all the actions are successfully done, the application main screen is then shown to the user (Figure 4.4).

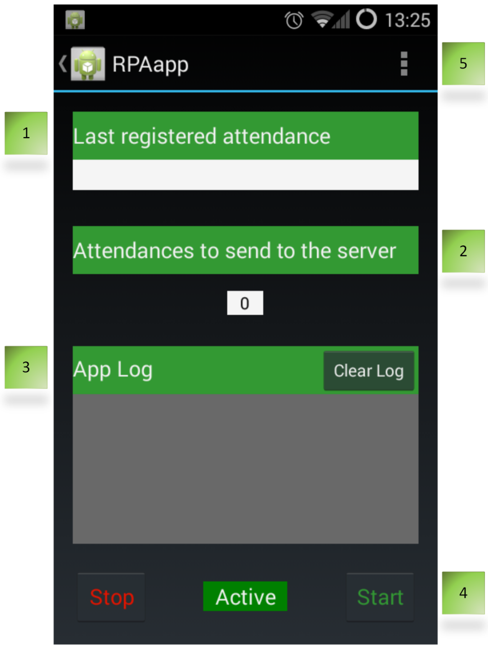


Figure 4.4: Application main window.

The main window (usually called of main activity in Android) is where the user is able to activate the service to automatically detect and register attendances. Nonetheless, if it is the first time running the application, some configurations are needed before the service is able to start. The main activity is divided in several different zones:

- Zone 1: Shows to the user the last registered attendance by the smartphone. It is empty when the app is running for the first time.
- Zone 2: As it will be explained later on this chapter, when the smartphone has no Internet connection, the attendance information cannot be sent to the server. Here is shown how many attendances are waiting to be sent.
- Zone 3: Log window to show the user the actions occurring in the background. Helps in the application configuration.
- Zone 4: Buttons to start and stop the attendance detection service.
- Zone 5: Access to other options.

The button in the action bar (zone 5) gives the user access to the application's configurations needed before being able to run (*Settings* and *Manage Doors*).

Manage Doors

To be able to detect virtual doors, the application needs to know the virtual doors installed in the building. To do that, the user must configure those virtual doors through the option *Manage Doors*. Here, two options are displayed in the screen: *Add New Door* and *List Doors* (Figure 4.5-a).

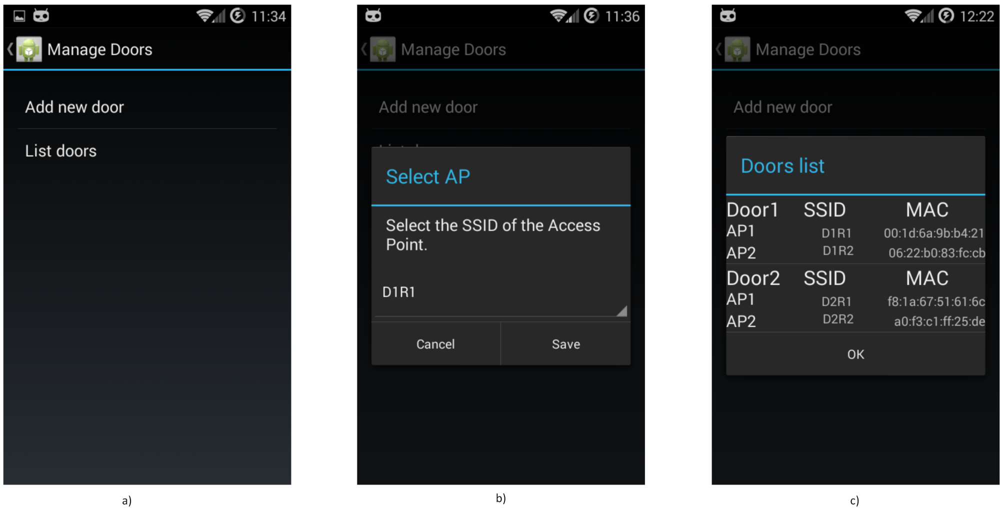


Figure 4.5: Manage Doors

Add a new door is a very simple action. The smartphone just needs to be in the range of the virtual door so it can detect both APs. At this point, the user is asked to select from the spinner list the first AP (AP1) (Figure 4.5-b). After selecting the first AP, the second access point (AP2) must be selected and it cannot be the same selected during the first step.

The door is now added and it can be seen in the list together with other already configured virtual doors by selecting the option *List Doors* (Figure 4.5-c). The data of the virtual doors saved during this process is the SSID and the MAC address of each AP. Although the SSID is not important for the application, it is the human-readable identification of the AP. The important data and the one the application works with, is the AP MAC Address because it is unique to each AP.

Signal Measurement

This tool (Figure 4.6) was developed to help with the configuration of the mobile application. By using it, the user can have access to the networks in the range and the signal power level received by the device (Zone 1). He/she can also have access to the maximum time the device needed to perform wireless scans (Zone 2). This is an important feature because network scan delays depend of the wireless adapter that the manufacturer installed in the smartphone. It means that, from the moment the network scan starts till the moment it finishes, not all the devices take the same time. For this reason, the configuration of the RPAapp must take this into consideration.

When the scan takes more than *Scan Period (sec)* to finish, the value shown in zone 3 is incremented by one. This gives an idea of how many times smartphone scans delayed for more than *Scan Period*, being a good indicator about the possibility to use the smartphone to control attendances.

Finally, zone 4 represents a log screen where the user can see a scan history. This can be useful to simulate a clock in/out movement, giving an idea about APs's signal power strength to allow to correctly configure the application in the *Settings* menu.

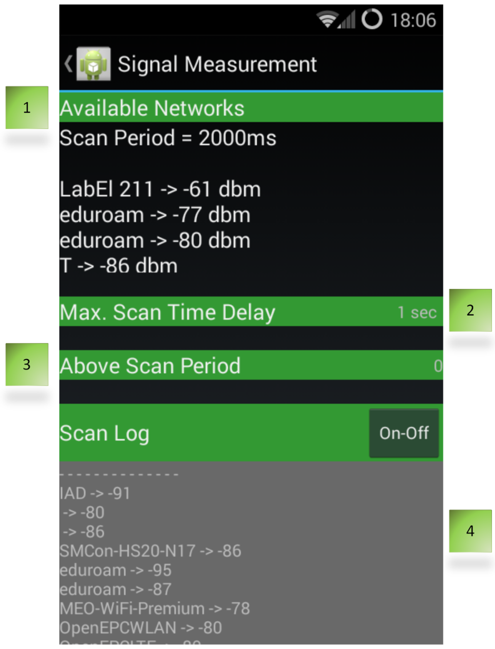


Figure 4.6: Signal measurement tool.

Settings

The *Settings* activity (Figure 4.7) may be the most important part of the mobile application, after the algorithm that detects virtual doors. Here is where the user should configure several parameters to allow the application to execute its functions correctly.

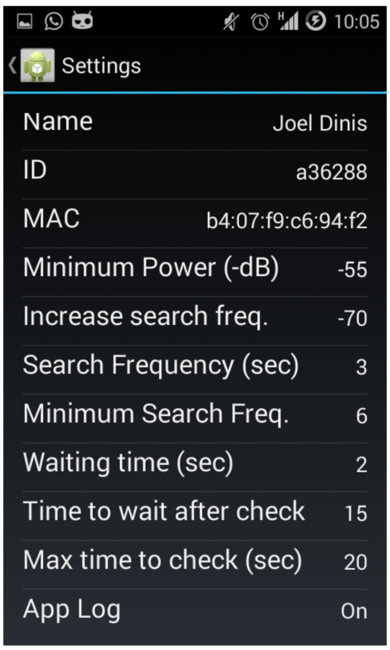


Figure 4.7: Settings activity.

As mentioned along this dissertation, there are several smartphone manufacturers and each of the them equip their devices with hardware from different providers. Even equipments from the same manufacturer are equipped with different hardware, it all depends of the smartphone models. This means that, from terminal to terminal, it's not just the design, processor or amount of storage that changes, GPS sensors may change, accelerometer hardware may change and, of course, the wireless adapter may also change. Because the application should work with all the devices, the application must be the more configurable possible. The *Settings* menu is the place where the user can configure it in order to achieve the best results.

The wireless adapter of the smartphone is the key hardware component for this project since it makes possible the wireless communication between the device and the APs. Through it, the smartphone obtains information like the SSID, MAC Address (also known as BSSID) and the RSSI of each AP.

Also because of the difference between the wireless adapters adopted for each model, the power level detected by each smartphone may be different even when smartphones are at the same time, at the exact same position and distance from the AP (Table 4.2). Sometimes, even when the smartphone is completely immobilized, the signal strength changes between two consecutive scans. This is due to the sensibility of the adapter and of course, due to reflexions and changes on the characteristics of the environment between the terminal and the AP.

Values in dBm

	4m	3m	2m	1m	0m	1m	2m	3m	4m
1m	-53	-47	-50	-41	-32	-43	-49	-55	-52
2m	-48	-49	-40	-38	-35	-36	-37	-46	-49
3m	-46	-39	-37	-35	-33	-38	-41	-42	-45
4m	-50	-43	-44	-36	-37	-40	-39	-43	-46

a)

Values in dBm

	4m	3m	2m	1m	0m	1m	2m	3m	4m
1m	-55	-58	-54	-51	-46	-47	-48	-56	-57
2m	-53	-54	-49	-52	-42	-49	-46	-50	-50
3m	-51	-52	-48	-50	-40	-46	-48	-47	-52
4m	-52	-50	-49	-46	-44	-49	-50	-47	-53

b)

Table 4.2: Wireless power level values captured at the same time and position by an Huawei G330 (A) and a Samsung Galaxy S i9000 (B) smartphone inside an 8x4 meter area near an AP.

Once the values are in dBm, when the level decreases 3dB it means that the signal power was reduced by about one half. Making the calculations, in almost 87% of the measures, the power level measured by the Huawei smartphone was at least 3dB higher than the values measured by the Samsung smartphone.

Analyzing the table 4.2, it can also be concluded that there are differences between values measured by each smartphone (sometimes the difference is even greater than 3dB). Thus, this confirms that the behavior of the wireless adapter differs from device to device, requiring the application to be configurable in order to work in every smartphone.

Therefore, in the *Settings* activity shown in Figure 4.7, besides the possibility to change the user's name and ID, and to see the MAC address of the device, there is also the possibility to change the following parameters:

- Minimum Power (dBm)
- Increase Search Frequency (dBm)
- Search Frequency (seconds)
- Minimum Search Frequency (seconds)
- Waiting Time (seconds)
- Max. Time to check (seconds)

This variables are not directly related with the detection of a passage through a virtual door. They were created thinking about the battery life of the smartphone since continuous wireless scans may significantly decrease the battery life.

Detecting passages through virtual doors requires several network scans and samples to be analyzed. Continuous scans for virtual doors when the smartphone is away from them is an unnecessary job. These scans should be made with less frequency when the smartphone is away and with higher frequency when they are in the range.

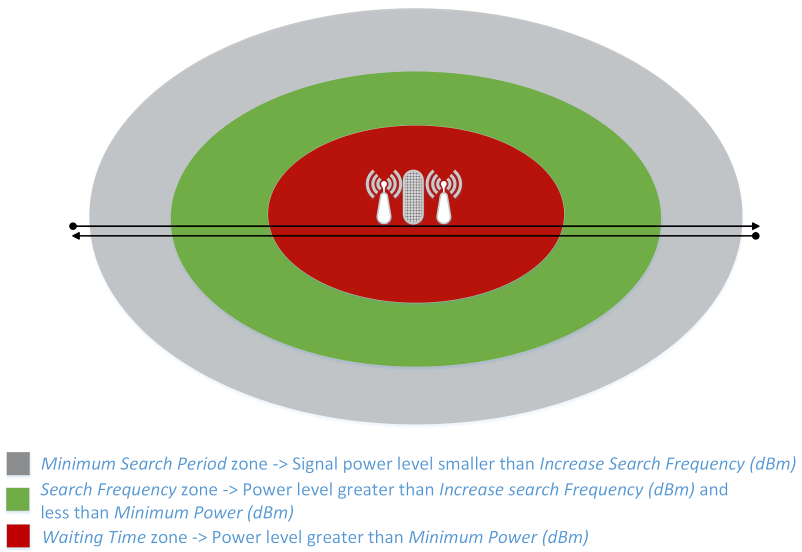


Figure 4.8: Different power level zones to control scan frequency.

Figure 4.8 shows three different zones where the application has different behaviors.

The gray zone represents a zone away from the virtual door. When inside this zone, the application performs wireless scans every *Minimum Search Frequency* seconds to detect if there are virtual doors in the range.

When the signal power level detected is greater than *Increase Search Frequency (dBm)*, virtual doors are considered to be near the smartphone (green zone). At this moment, the smartphone starts scanning at higher frequency (*Search Frequency*) to find out if the user is getting closer to the door.

Although near, the application only assumes to be really close to a virtual door when the RSSI detected from one of its APs is above *Minimum Power (dBm)* (red zone). When inside this zone the application starts to perform scans even more frequently, with a *waiting time (sec)* between each scan to acquire RSSI values to be processed later and decide if the user was entering or leaving.

Data acquisition only stops when the user leaves the red zone (initiating the analyzes of the samples) or if the user is inside the red zone for more than *Max.Time to check (sec)* (excluding the data in this case).

Finally, the user has the possibility to control the time between consecutive attendances by defining the *Time to wait after check* variable. This is a feature that almost all the attendance systems have to avoid the registration of consecutive attendances in a short period of time.

The Android application service

After all the configurations are finished, the application is ready to start to perform its real function: detect and register attendances. When on the main activity, pressing the *START* button located at the bottom of the screen, will start what is called an *Android Service*.

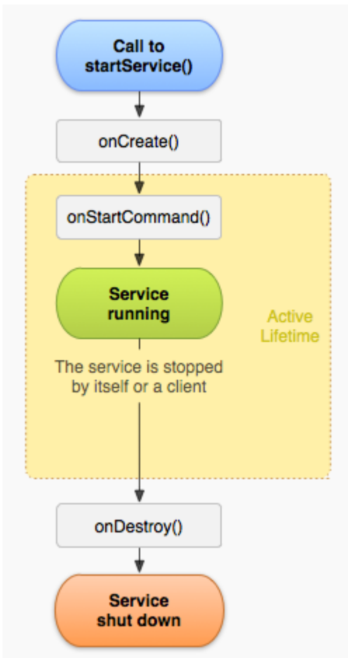


Figure 4.9: Android Service life cycle.
[34, Source: Google developers website]

Google describes a service as "an application component that can perform long-running operations in the background and does not provide a user interface." [34]. Once the application needs to continuously run in the background without needing any intervention from the user (no user interface is needed), Android Services are the base component to use. When the user presses the start button, the service is initiated and starts to run in the background of the operating system. After that, the user can leave the application and use the smartphone to make calls, access the Internet, send a message, listen to music, etc., without compromise RPAapp's operations.

Figure 4.9 represents the Android service life cycle. When the service (*InOutService.java*) starts, it first runs the *onCreate()* method. Within this method, all the parameters from the *Settings* activity are loaded together with the information about configured virtual doors in the *Manage Doors* activity. When all this information is available, the service setup finishes, starting its active life cycle when the *onStartCommand()* method is called. Since the moment it starts till the moment the user clicks the *Stop* button on the main activity (*onDestroy()* method), the application will be scanning for virtual doors in the area to register attendances. The application can just be stopped by the user, or by the operating system if the resources used are needed to perform other operations. If this happens, the operating system will restart the service when the resources are free again.

4.2.4 Acquisition of APs signal samples

When the Android application service is started, wireless scans are performed to detect virtual doors, acquire signals' RSSI and register attendances.

Like referred when RPAapps's different phases were introduced (Figure 4.1, page 24), application's first step is to detect virtual doors. Remembering the process described on page 32, a virtual door is considered to be in the range when the smartphone is inside the green zone or, in other words, when the RSSI of the signals sent by one of the APs is greater than the *Increase Search Frequency* value.

Nonetheless, the acquisition of signal samples starts only when inside the red zone (i.e. RSSI of one or both APs above *Minimum Power*) once it is the zone where the smartphone is considered to be really close to the virtual door. The acquisition process finishes when the smartphone leaves the red zone or is inside it for more than *Max Time to check (seconds)*.

A schematic representation of the detection and samples acquisition blocks is shown in Figure 4.10.

4.2.5 Process acquired samples

When the smartphone leaves the red zone, the application has in memory several signal RSSI values collected from each AP of the virtual door. These values are then used by a developed method called *checkInOutAlgorithmMethod*. This method consists in an algorithm developed to process the data collected and, depending of the results, give the order to register the attendance.

In order to develop this algorithm, several tests were made to better understand the behavior of the APs' RSSI in the virtual door's area. This allowed to get conclusions about the best way to process the data to achieve a result that may help to decide what type of movement it was: a check in or a check out movement.

These tests consisted in performing several simulations of entrances and exits, collecting the APs' RSSI using the developed tool *Signal Measurement*. Figure 4.11 shows the RSSI variations for two different simulations made.

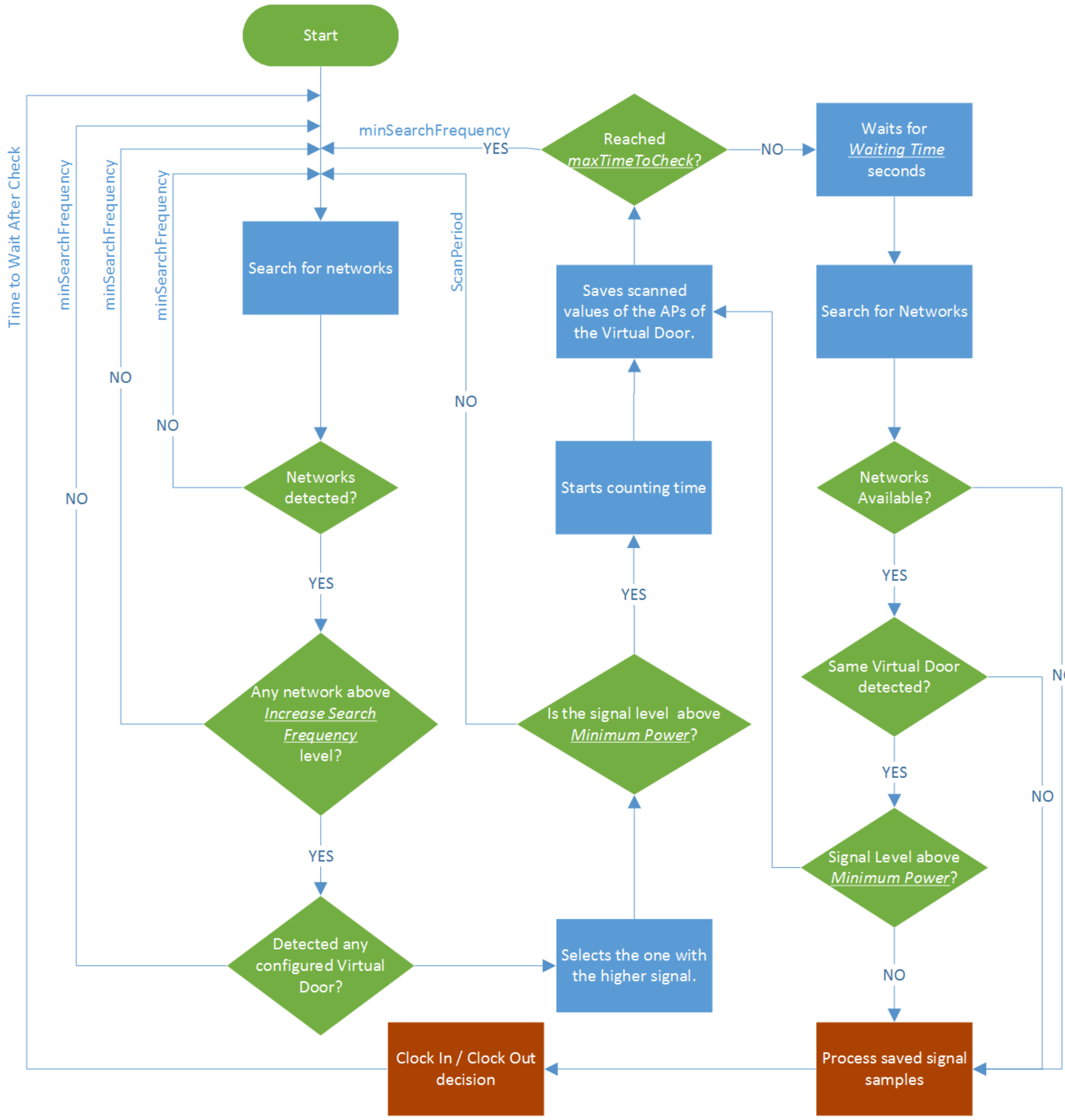
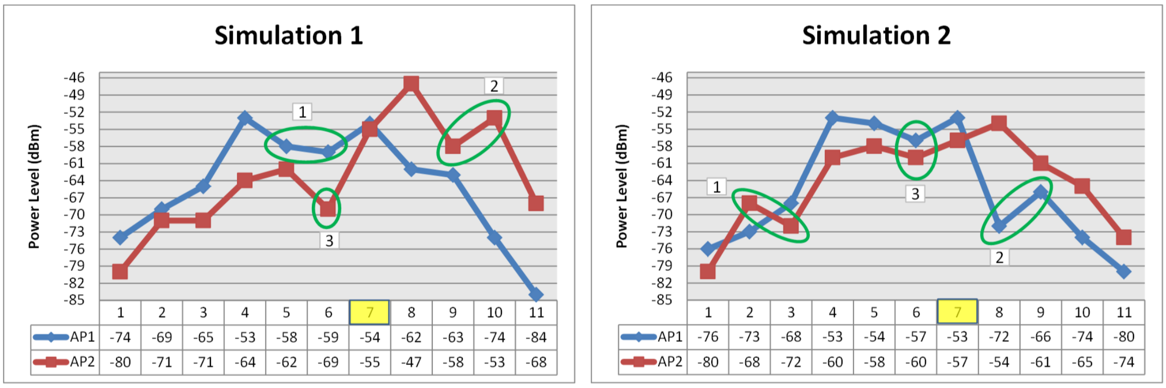


Figure 4.10: Virtual doors detection and RSSI samples acquisition flowchart.



(a) (b)

Figure 4.11: APs power level detected during two simulations of a check in movement.

It was known that the detected RSSI depends of the smartphone and that it exists some fluctuations between two consecutive scans even when the smartphone doesn't move.

These simulations demonstrates another (already expected) characteristic: that it is hard to have two similar *Check In/Out* scans. Figure 4.11 shows how much two entrances, using the same device and walking through the exactly same route, can be different.

An important characteristic visible on both graphics is that the fact of being closer to the APs doesn't always mean that the RSSI is better. In fact, in Figure 4.11a, points 1 and 3 are points where RSSI decreases when it was expected to increase since the virtual door was getting closer. The same happens in simulation 2 (Figure 4.11b) although not so significantly (point 3). The opposite is also verified, i.e., when the smartphone was getting distant from the APs, RSSI was expected to decrease but point 2 (simulation 1 and simulation 2) proved that this behavior can change from scan to scan.

It is also important to notice that, before the virtual door (entrance movement), AP1 RSSI levels are usually higher than the AP2 RSSI levels. This occurs if between the APs is an attenuating material or enough distance to force the signal from the distant AP to be weaker than the near AP signal. A similar behavior is also verified when in the other side of the virtual door where AP2 RSSI tend to be greater than AP1 RSSI.

Nonetheless, this usually happens but it is not one hundred percent sure. In fact, the second measure of simulation 2 (point 1) shows a situation where power level of AP2 was greater than AP1 level when it wasn't expected to be since it corresponds to a measure made before entering the room.

Summarizing, there are several problems to deal with:

- Even using the same device, different check in/out movements usually have different scan results.
- Being closer to an access point doesn't always mean that the scan will return greater RSSI levels.
- Before the virtual door, the RSSI from the closest AP isn't always higher than the RSSI from the distant AP. The same can happen when in the other side of the virtual door.

These problems forced the algorithm to be developed in a way that, independently of the difference between scans, when the samples are processed, results must be the same for each different device. That is why APs' signal behaviors, tendencies or values should not be compared with pre-established data since each check-in/out movement is different.

Considering that samples may have strange behaviors, not all the samples are important for the movement decision. To decide what samples are more important to process, it was necessary to understand the behavior of the signals in the zone near the virtual door. Figure 4.12 represents the RSSI levels measured inside an area of 32 square meter near a virtual door (outside the virtual door).

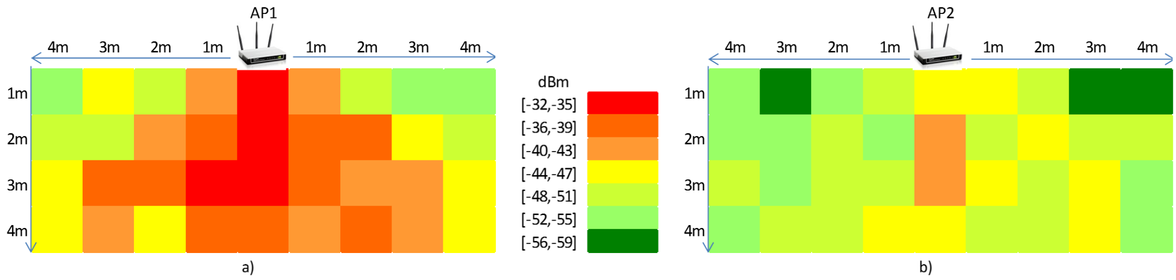


Figure 4.12: Received signal strength in the area of a virtual door. APs were separated by a 20cm brick wall and the AP1 was the closest to the smartphone (Samsung Galaxy S i9000 model).

Analyzing Figure 4.12 it is possible to confirm that the nearest AP is the one the smartphone detects with greater RSSI.

When near the virtual door, RSSI values are saved by the smartphone. Depending on the configurations and movement speed of the device, because the smartphone has three different scan frequencies (*Minimum Search freq*, *Search frequency* and *Waiting time*), the samples acquisition process may start when the user is 4m away from the virtual door or when it is just 1m away. There is no way to know when and where the samples start be saved.

To guarantee that the mobile application produces reliable results, the decision about the movement direction when crossing through a virtual door must be made through several scan samples, and these samples must be obtained in the area where RSSI is better.

Although it is impossible to guarantee various scans near the first AP due to the problem referred before, it is possible to guarantee more scans in the zone where the second AP is the one with the better RSSI.

Producing results based just on the scan samples acquired after pass through the virtual door, i.e.,inside the zone where the second AP has better coverage, ensures that samples are enough to make a good decision about the movement direction, at the same time it reduces the probability of unexpected RSSI variations like the ones shown in Figure 4.11.

The developed algorithm used by the application to decide if it is a check in or a check out movement follows the next steps:

1. Search all the samples acquired to find the better RSSI of each AP.

2. Find out which of these two RSSI samples occurred in the last place.

3. Find out what sample corresponds to the moment where the RSSI is lower again than the *Minimum Power)* (means that the smartphone abandoned the red zone).

4. All the samples between the two previous samples (called from now on Attendance Samples (AS)) are the samples used to make a decision about the movement direction.

4.2.6 Clock In / Clock Out decision

The determination of the movement direction of the smartphone is made using the samples returned by the previous block. Attendance samples are the samples collected after the moment the second AP becomes the one with better RSSI. Nonetheless, it was seen that, sometimes there are some samples where this doesn't happen. To prevent these exceptions of causing problems, RPAapp calculates the average power level of each AP using AS values in the equation 4.1.

$$\overline{APx_{RSSI}} = \frac{\sum_1^n AS_i|_{APx}}{n} \tag{4.1}$$

where x is the number of the AP (1 or 2) and n is the number of scanned attendance samples for the APx.

By calculating the mean RSSI of the attendance samples for each AP, an abrupt variation of a sample that may have occurred, is divided by n. For example, if a sample corresponding to the near AP unexpectedly drops 10dB, causing the sample to be below the RSSI measured from the distant AP, if five Attendance Samples are collected (n=5), it means that the final result, after calculating the mean RSSI of each AP, will be affected by only 2dB. Once the difference between the signals from the two APs tends to be much more than 2dB, it means that it is not probable this abrupt variation influence the decision about the movement direction.

The decision algorithm uses then the result of the mean RSSI obtained using equation 4.1 to decide the movement direction made by the smartphone holder. The decision algorithm is simple: if AP1 mean RSSI is greater than AP2 mean RSSI, it was a *check out* movement, if the opposite is verified, it means that it was a *check in* movement.

To better demonstrate the process, Figure 4.13 shows samples captured when performing a *check in* movement and the *Settings* configurations at the time.

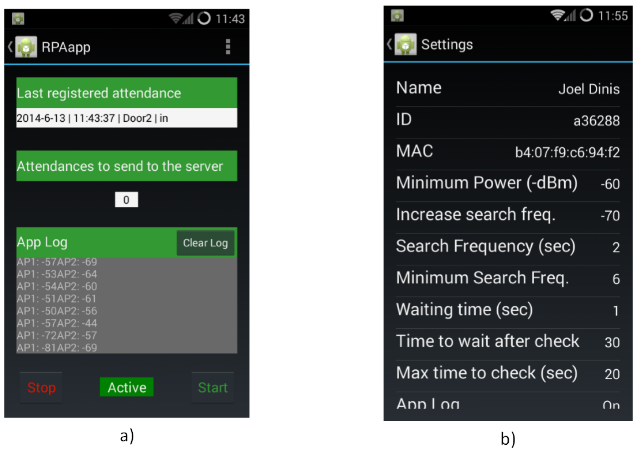


Figure 4.13: *Check In* movement samples captured by the smartphone (a) and the *Settings* configurations at the time (b).

dBm

AP1	AP2
-57	-69
-53	-64
-54	-60
-51	-61
-50	-56
-57	-44
-72	-57
-81	-69

a)

dBm

AP1	AP2
-57	-44
-72	-57
-81	-69

b)

dBm

AP1	AP2
-70	-56,6667

c)

Figure 4.14: *Check In* samples captured by the smartphone (a), attendance samples used by the decision algorithm (b) and the RSSI mean calculation results (c). The yellow rectangles represent the maximum RSSI detected for each AP.

At this point, all the process since the detection of virtual doors till the movement decision can be summarized and easily understood.

Taking into account the *Settings* configurations (Figure 4.13-b), after the service is initiated, the smartphone starts to scan for virtual doors every 6 seconds (*Minimum Search Frequency*). When a network above -70dBm (*Increase Search Frequency*) is found, scans start to be performed every 2 seconds (*Search Frequency*) because a virtual door may be in the range.

If the network RSSI becomes stronger than -60dBm (*Minimum Power*), the application assumes the smartphone holder is passing through a virtual door so it starts the samples acquisition process with a *waiting time* of 1 second between each scan (plus the time each smartphone needs to perform the scan).

When both of the networks have a RSSI lower than *Minimum Power* (-60dBm), the application service stops the acquisition process and starts to process the acquired samples (4.14-a).

The process of the samples follows the steps explained in the *Process acquired samples* subsection. Just the samples measured after the moment the last maximum was detected counts so, just the samples measured after the AP2 RSSI equal to -44dBm (this sample is also included) will be part of the Attendance Samples used in the *decision algorithm* (4.14-b).

Finally, the decision algorithm calculates the mean RSSI of each AP through the equation 4.1 obtaining the result shown in Figure 4.14-c.

Since AP2 mean RSSI is greater than the AP1, it means the last AP of the virtual door is the AP2 so, remembering the convention established earlier in this project where the AP2 is the one placed in the "inside" side the virtual door, these samples represent a *Check In* movement.

The acquisition of APs signal samples and the *Clock In/Out decision* are made by a method named *checkInOutAlgorithmMethod()* inside the service class *InOutService.java*.

4.2.7 Send attendances to the server

After a successful detection of a movement through a virtual door and the respective movement direction, the mobile application collects some important data like the date, time, door where the movement occurred and the direction of the movement.

As referred before, the AP of the virtual door may not have a connection to the Internet so, it is possible they do not provide an Internet connection to the smartphone. This is not something prohibitive. If the company or school that adopts this system wants to provide access to the network through those APs, it will not be any problem at all. But, because that is not guaranteed, the mobile application was developed to be ready to the absence of Internet at the moment the attendance is detected.

For this reason, an internal database was developed in order to save each attendance until the moment the server receives this data. The number of attendances waiting to be sent is displayed to the user in RPAapp's main activity.

In Android-based devices, there are two types of Internet connectivity: Wi-Fi or through the mobile network. To detect when the smartphone has Internet connection, the application uses an Android component called *Broadcast receiver*[35]. By using this component, the application is able to register a request to the system to be notified when an event happens. When an attendance is saved in the internal database, a broadcast receiver is registered to be notified latter when the smartphone has Internet connection through Wi-Fi or mobile network.

When the receiver is notified that Internet connection is available, the created Java class *NetworkStateReceiver.java* is executed, starting a series of actions in the background (Figure 4.15):

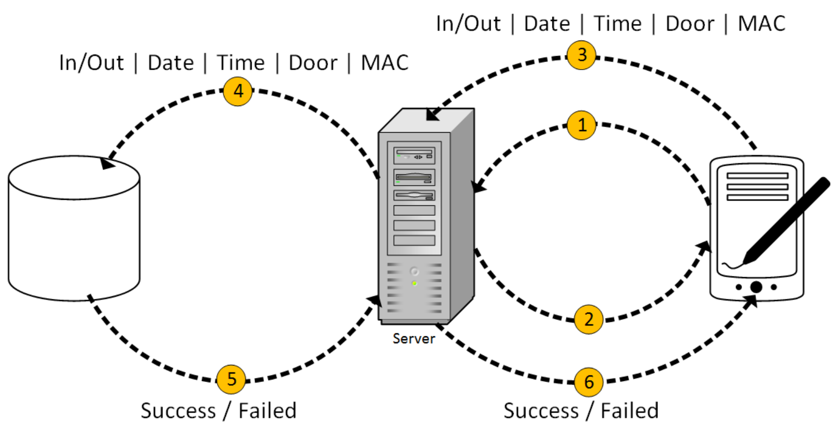


Figure 4.15: Actions made by the RPAapp when an Internet connection is available and there are attendances to send to the server.

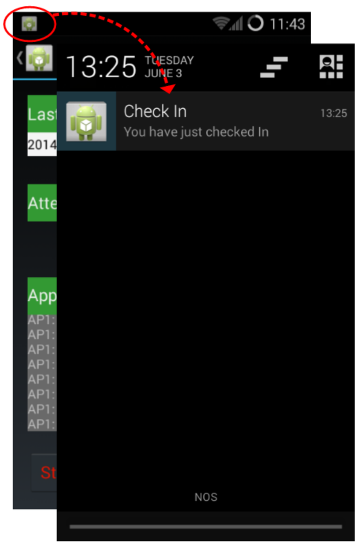
The application starts by sending a message to the server to confirm the connection is available(point 1) and waits for a *success* message sent by the server (2). After receive the confirmation that the web server can be reached, all the information saved in the internal database is sent to the server. It can be just one attendance or several attendances, they are all sent to the server (3) in the same message. When the server receives the message, it tries to save it in the database (4). Whether the information is saved or not (5), the server sends a message back to the smartphone indicating the success/fail of the process (6). The internal temporary database is cleaned just when the process is marked as successful.

The RPAapp uses the Hypertext Transfer Protocol (HTTP) protocol to deliver the data to the server. To send the information it is used the HTTP POST request method so the web server accepts and saves the data enclosed in the message sent by the smartphone.

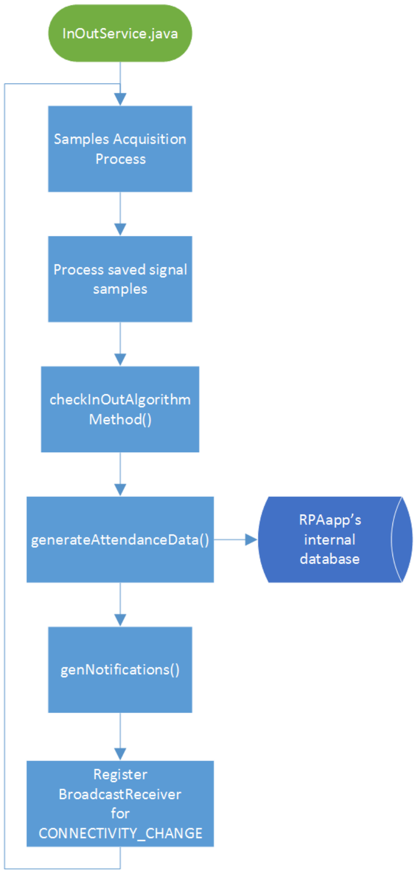
4.2.8 User notifications

Since the attendance registration is completely automatic, the smartphone holder doesn't need to hold the smartphone in his/her hands. In fact, the equipment can be in the pocket or in the bag, it doesn't matter because the RPAapp doesn't need any user intervention.

Nonetheless, to inform the user that the attendance was registered, the application notifies the user about the event by playing a sound and/or vibrating (it depends of the user profile configured in the smartphone). Because the smartphone holder can feel the vibration or the sound played by the device, he/she can confirm that the movement through the virtual door was detected and registered without needing to interact with the smartphone.



(a) Notification message generated by the RPAapp to notify the user about an event.



(b) RPAapp's flowchart of the methods executed when an attendance event occurs.

Figure 4.16: User notification example and flowchart.

At the same time, a notification message is generated to display the user that an event has occurred. Android notifications allow the application to notify the user about some event, without needing to have the application's User Interface (UI) on the screen.

First, the notification is shown in the *notification's area* in the form of a small icon equal to the RPAapp's icon. The user can then see the details of the notification by sliding down the bar. At this time, the icon is shown together with a message indicating the type of attendance registered (*Check In / Check Out*) and the hour when the event happened (Figure 4.16a).

4.2.9 Fetch attendances from the server

One of the project's main objectives was to give access to registered attendances at anytime and anywhere since there is a connection to the Internet and a smartphone.

The idea is to allow the users to have access to their own attendances and to allow an employer to have access to their employees attendances, or a professor or parents to control their students/sons attendances.

The application also gives the possibility to see if the user was late or left earlier his/her workplace. In order to allow those notifications, the user's work schedule must be registered in the server's database.

At this moment, the database is ready to save a work schedule composed by two time intervals: *clock in time 1*, *clock out time 1*, *clock in time 2* and *clock out time 2*. This simulates a typical work schedule where a person gets to the job site, then leaves for lunch and returns after lunch, leaving the place at the end of their shift.

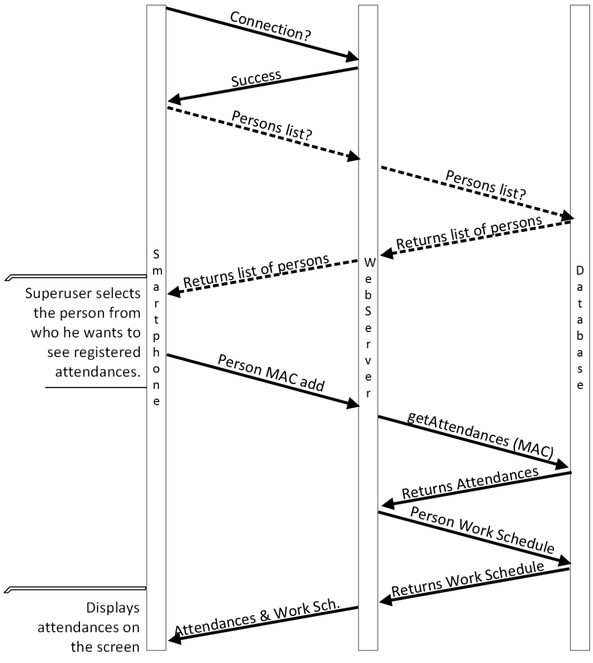


Figure 4.17: Stored attendances acquisition process. The dashed lines represents a particular process only performed when a superuser (employer/professor/parents) wants to check someone's attendances.

Figure 4.17 is a schematic representation of the attendances acquisition process. There are two possible ways to view registered attendances stored on the server: view user's own attendances or view others' attendances.

An user can view his/her own attendances by selecting the option *Show My Attendances*. The option *Show others attendances* gives the possibility to view other users' attendances.

As Figure 4.17 shows, both processes are very similar, the only difference is the fact that, to view other person's attendances, the user must select first, the person he/she wants to see (represented by dashed lines).

The process is very simple and can be resumed in just a few steps:

1. The smartphone sends a message to the server and waits for an answer to check if there is Internet connection to allow communications between them.

2. If a person (employer/teacher/parent) wants to see others' attendances, the smartphone sends a message to the server asking for a list of registered users.

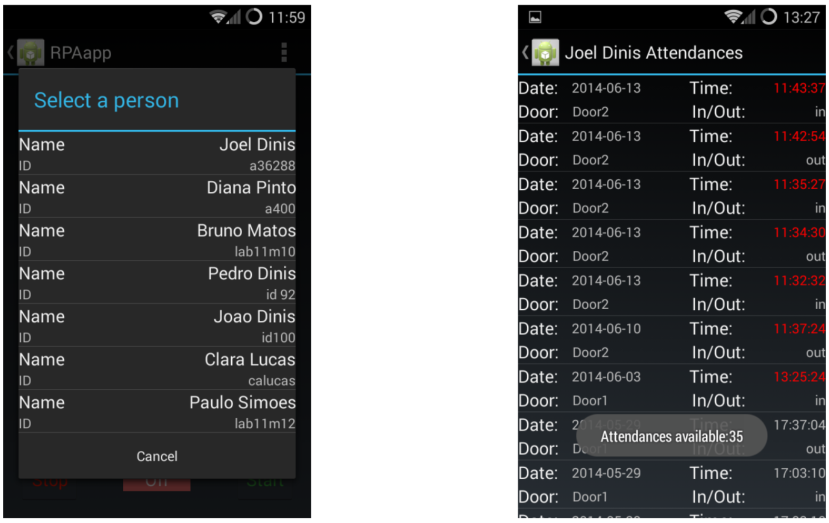
3. Server gets the list from the database and sends it back to the smartphone together with the MAC address of each user.

4. User selects a person from the list (Figure 4.18-a).

5. The MAC address that represents the selected person is sent to the server together with a message asking for the corresponding attendances.

6. Server gets the list of attendances from the database together with that person's work schedule and sends all this data back to the smartphone.

7. The application receives the message and shows the information to the user (Figure 4.18-b)



a) b)

Figure 4.18: Application dialog window containing the list of persons to select the one to see attendances of (a) and the respective list of attendances (b).

When attendances are shown in the application's screen, the user has access to the date and time when each attendance was registered, together with the virtual door and the direction of the movement. To facilitate the analysis of the list, the time when they were registered is shown in red if it represents a delay or an early exit.

4.3 About RPAapp

The mobile application designed for this project was developed using Ecliplse IDE with built-in ADT (Android Developer Tools) software [36]. The application was developed for the Android operating system and it is available for all the smartphones and tablets equipped with an Android version between Android 2.1 and the last Android version (4.4).

The released APK file corresponding to the final version of the application, allows the installation of the app at all the devices referred above. When installed, the application occupies about 2.3 megabytes of storage space. In terms of RAM, when the background service is running, it consumes about 18 megabytes of memory.

Before the installation, the user is asked to accept some permissions needed by the application to work. These permissions are defined in the project's *AndroidManifest.xml* file and are the following:

- *ACCESS_WIFI_STATE* - Allows application to access information about Wi-Fi networks.
- *CHANGE_WIFI_STATE* - Allows application to change Wi-Fi connectivity state.
- *INTERNET* - Allows applications to open network sockets.
- *WAKE_LOCK* - Allows using PowerManager WakeLocks to keep processor from sleeping.
- *VIBRATE* - Allows access to the vibrator.

Since the application was developed using JAVA programming language which is object-oriented, three different objects were created for the purpose of this project:

- Door object. This object is composed by the fields:
  - door name, ap1SSID, ap2SSID, ap1BSSID, ap2BSSID, ap1RSSI, ap2RSSI.
- Attendance object. This object is composed by the fields:
  - In/out movement, date, time, door, MAC address.
- Person object. This object is composed by the fields:
  - Name, ID, MAC address.

All these objects are also composed by all the object's methods to get and set these fields' values (data encapsulation).

As explained on chapter 3, an Android application uses activities to interact with the user, so the Activity class takes care of creating a window containing the user interface. To interact with the user, the RPAapp is composed by 6 different activities also defined in the manifest file:

- MainActivity.java - the main application window.
- SettingsActivity.java - where the user can configure the app.
- ManageAPsActivity.java - where the user can configure virtual doors.
- MyAttendancesClass.java - shows user registered attendances.

- PersonAttendancesActivity.java - shows other users registered attendances.

- SignalStrengthMeasure.java - runs the *Signal Measurement* tool.

All these Activity classes are composed of methods (named as functions in other programming languages). These methods were developed to execute different functions in order to achieve the desired behavior. Schematic representations of some activity's execution-flow are shown next.

4.3.1 MainActivity and SettingsActivity

Figure 4.19 shows *MainActivity.java* and *SettingsActivity.java* main methods developed and their execution sequence.

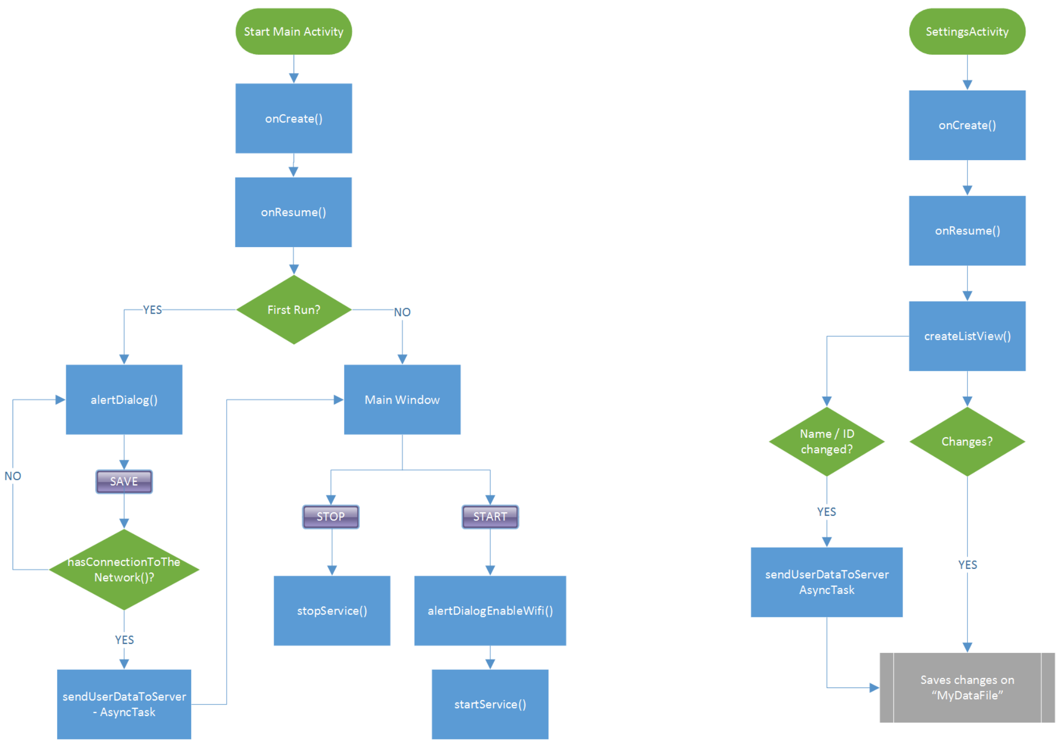


Figure 4.19: RPAapp main activity and settings activity execution flowchart.

4.3.2 ManageAPsActivity and PersonAttendancesActivity

Figure 4.20 shows *ManageAPsActivity* and *PersonAttendancesActivity* main methods developed. Methods developed for *MyAttendancesClass* are basically the same of *PersonAttendancesActivity*, only the information exchanged with the server is different.

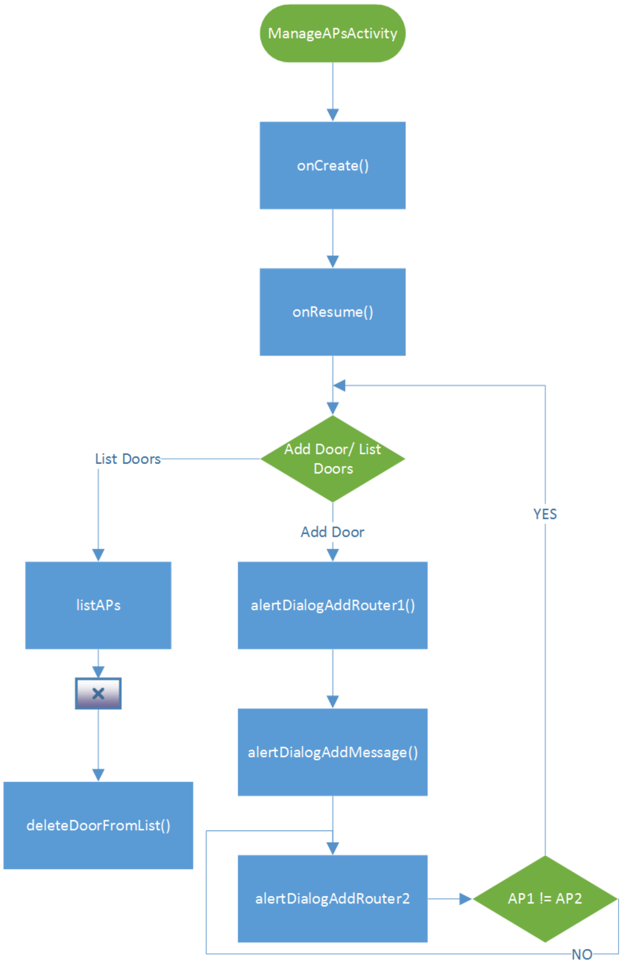


Figure 4.20: RPAapp ManageAPs activity and PersonAttendances activity execution flowchart.

Chapter 5

Tests and results

5.1 Summary

This chapter aims to validate the developed mobile application testing it in terms of battery consumption, influence of the wireless adapter delay to get the scan samples, and finally, to test the whole system with virtual doors installed in different places and conditions.

5.2 Hardware devices tested

To perform these tests, four APs were used together with three Android-based devices (two smartphones and one tablet).

- Two TP-Link APs, model No. TL-WR1043MD, Version 1.11 [37]
- Two TP-Link APs, model No. TL-WR1043MD, Version 2.1 [4]
- Samsung Galaxy S i9000 smartphone [2] with Android version 4.4.2
- Huawei G300 smartphone [38] with Android version 4.0.3
- Samsung Galaxy Tab2 [3] with Android version 4.1.2

5.3 Battery consumption

These tests were made to test the battery consumption of the RPAapp and analyse the impact it may have in the daily battery lifetime. The tests were executed using the three Android-based devices referrer above.

	Samsung Galaxy S	Huawei G300	Samsung Tab 2
Time since last charge	7h27m	16h26m	15h44m
% of battery spent	68%	44%	22%
% spent by RPAapp	28%	27.3%	17.8%
% spent by GSM	-	43.7%	-
RPAapp running time	6h38m	9h31m	9h53m
Min Search Frequency (sec)	5	5	5
Number of scans	aprox.4770	aprox. 6850	aprox. 7116
Battery capacity	1500mAh	1500mAh	4000mAh

Table 5.1: Battery consumption statistics.

Table 5.1 shows the statistics related to the battery consumption of each device. The conditions of the tests were basically the same for each of the smartphones, but it must be taken into consideration the fact that they are different devices, with different characteristics where the difference between the battery capacity and health may be important when comparing the results.

The Huawei G300 smartphone had the RPAapp running for approximately 58% of the time the smartphone was discharging. During that time, 44% of the smartphone's battery was spent, 27% by the application and 43.7% by the GSM antenna. Nonetheless, GSM battery spent is related to the *Time since last charge* so, during the *RPAapp running time* the GSM is only responsible for approximately 25% of the battery spent, which means that the application is consuming approximately the same battery as the GSM. Since the Samsung tablet doesn't have GSM hardware and it has a battery with more capacity, the device's *battery % spent* was smaller but during the 9h53m the application was running in the background, it spent 17.8% of the battery spent.

The Samsung Galaxy S was the device with the worst results. This may be related with the age of the battery (four years old). Usually this device has eleven/twelve hours of battery with one charge and after running the application for 6h38m it still had 32% so, running the application may had consumed about one hour and half of battery.

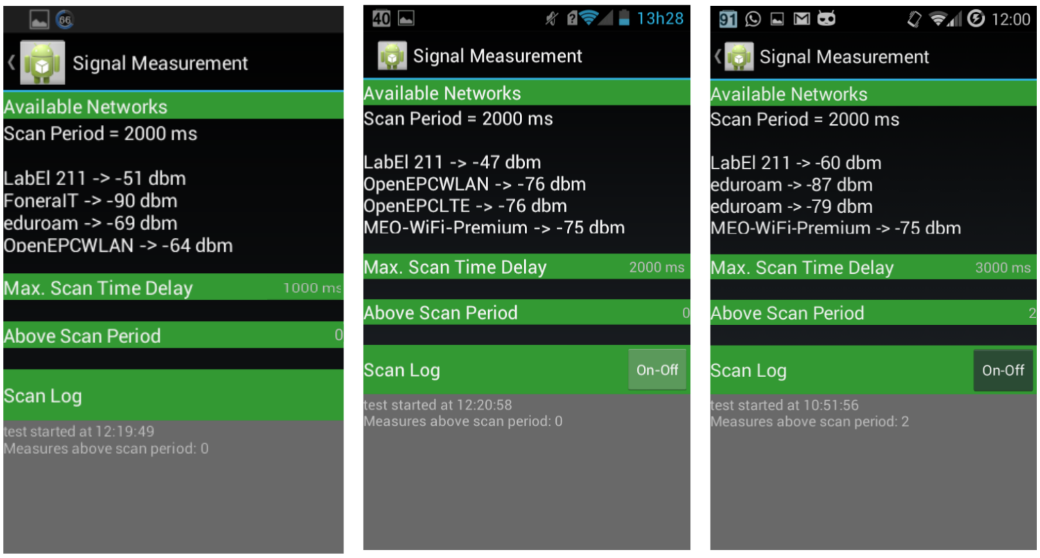
Also during the time the application was running, more than 6850 scans were performed by the Huawei device, more than 7116 scans by the Samsung Galaxy Tab2 and aproximatly 4770 for the Samsung Galaxy S. Once during this time period the devices weren't near any virtual door, these numbers represent the minimum number of scans performed during this time (*Minimum Search Freq* was configured to five seconds). This means that these numbers tend to increase when the smartphone detects virtual doors in the range once it changes the scan frequency in these conditions.

When the smartphone's Wi-Fi adapter is switched on, the Android OS automatically scan for new networks with a frequency of approximately eight seconds. These scans, together with the RPAapp scans, will represent a huge number of scans after several hours. Because RPAapp's scans when far away from virtual doors are unnecessary, they represent a great amount of wasted battery. To reduce the number of unnecessary scans, two possible solutions are pointed in the *Future Work* section of the last chapter.

5.4 Wireless adapter behavior

This test was planned to test the wireless adapter behavior. To do that, the three devices were running the *Signal Measurement* tool for more than one hour, performing a wireless scan every two seconds. This test was made with several APs in the range of the smartphone to intensively test the scan capabilities of the smartphone's wireless adapter.

At the end of the test, the following information was available: the largest delay of a scan and how many scans took more than *Scan period* to complete. These values allow to conclude about the capability of the device to execute the scan task once, the more constant and small the scan delay is, better for the RPAapp. Figure 5.1 shows the results of the test:



a) b) c)

Figure 5.1: *Signal measurement* tool results after test the devices' wireless adapter. (a) Samsung tablet, (b) Huawei G300, (c) Samsung Galaxy S

At the end of the test, after scanning for about fifty-eight minutes, the Samsung tablet made more than 1500 scans and none of the scans delayed for more than one second (Figure 5.1-a).

The Huawei smartphone was running the *Signal Measurement* tool for about one hour and eight minutes. During this time, more than 2000 scans were performed and any of them took more than *Scan Delay* to complete. Nonetheless, the *Max Scan Time Delay* detected was two seconds so, at least one scan took more than one second to complete (this didn't happened during the tablet test).

The Samsung Galaxy S was also running the same tool for about one hour and eigth minutes. During this time, the maximum delay to get scan values was three seconds and it happened two times. Nonetheless, these two scans represent only 0.1% of the performed scans (aprox. 2040) so there is no need to believe this smartphone is not good to run the RPAapp.

It was also possible to test another equipment during this test, the Samsung Galaxy S2 Plus, with Android 4.1. The results are shown in Figure 5.2:

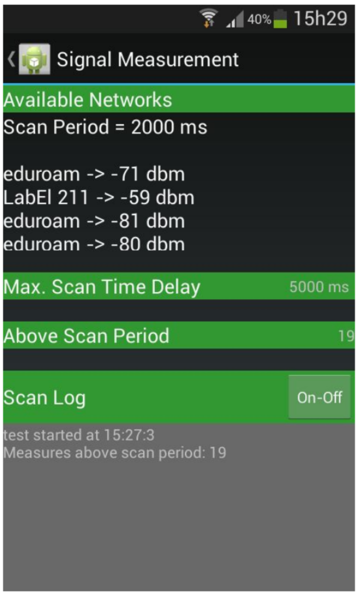


Figure 5.2: Wireless adapter

This test lasted only one minute and a half but it was more than enough to discover that the Samsung Galaxy S2 Plus can't be used to detect virtual doors because it will loose most of the samples that should be saved during the check in/out movement (all the scans lasted more than *Scan Period*).

Some entrances and exits were also made to test the implications that this behavior could have. Most of the movements weren't detected by the smartphone and the decision process of those that were correctly detected was based in just one or two acquired samples.

This seems to be caused by hardware and/or drivers limitations and not by an excessive load of work to manage by the operating system once, in this case, there were just basic processes running on the background. Hence, this test demonstrates that not all the smartphones can run the application and be able to detect all the movements across virtual doors.

5.5 Tests to the entire system

These tests aimed to test the entire system (RPAapp, virtual doors and server). Virtual doors were installed in several different places and conditions: APs separated by an attenuating material (wall) or separated only by a certain distance.

The idea was to simulate different places and conditions where the system can be used. All the tests were made inside the building *Instituto de Telecomunicações* at the University of Aveiro and with the Huawei smartphone in one pocket, the Samsung tablet placed inside a bag and holding the Samsung Galaxy S in the hand.

5.5.1 Virtual doors installed along a corridor

This test aimed to test situations where the APs of the virtual door are not separated by an attenuated material but by a certain distance. To achieve that, the APs were installed along two of the corridors of the building. It was also tested the possibility to use two different virtual doors to detect the movement.

Figure 5.3 shows how virtual doors were installed and the path followed: Enter at door number one, exit at door number two, enter at door number two and finally, exit at door number one.

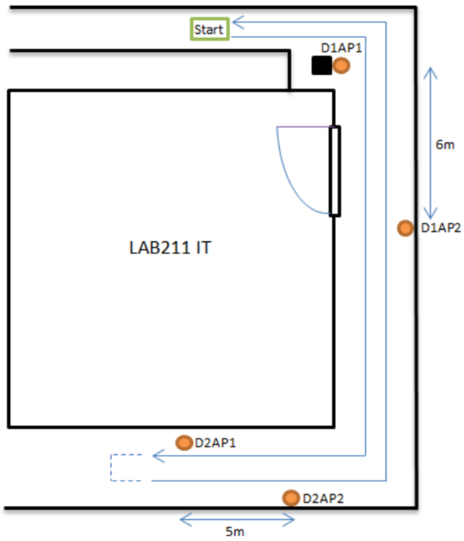


Figure 5.3: Corridor plan showing where virtual doors were installed.

For this test, smartphones' *Settings* configurations were the following (Figure 5.2):

	Samsung Galaxy S	Huawei G300	Samsung Tab 2
Minimum Power (dBm)	-60	-55	-50
Increase search freq.(dBm)	-75	-75	-70
Search Frequency (s)	2	2	2
Minimum Search Freq (s)	5	5	5
Waiting time (s)	1	1	1
Time to wait after check (s)	15	15	15
Max Time to check (s)	40	40	40

Table 5.2: Final configurations of RPAapp's *Settings* after running the corridor test.

attendanceid	inout	date	time	door
224	out	2014-06-19	20:24:36	Door2
223	in	2014-06-19	20:23:54	Door1
222	out	2014-06-19	20:23:14	Door1
221	in	2014-06-19	20:22:30	Door2
214	out	2014-06-19	20:21:54	Door2
213	out	2014-06-19	20:21:54	Door2
212	in	2014-06-19	20:20:43	Door1
211	out	2014-06-19	20:20:01	Door1
210	in	2014-06-19	20:19:09	Door2
208	out	2014-06-19	20:18:24	Door2
207	in	2014-06-19	20:17:44	Door1
206	in	2014-06-19	20:17:44	Door1
205	in	2014-06-19	20:17:44	Door1
204	in	2014-06-19	20:17:44	Door1
203	in	2014-06-19	20:17:44	Door1
202	in	2014-06-19	20:17:44	Door1
200	out	2014-06-19	20:17:08	Door1
198	in	2014-06-19	20:16:37	Door2
193	out	2014-06-19	20:16:00	Door2
192	in	2014-06-19	20:15:17	Door1
190	out	2014-06-19	20:14:37	Door1
189	in	2014-06-19	20:14:07	Door2
188	out	2014-06-19	20:13:25	Door2
187	out	2014-06-19	20:14:37	Door1
186	in	2014-06-19	20:14:07	Door2
185	out	2014-06-19	20:13:25	Door2
184	out	2014-06-19	20:14:37	Door1
183	in	2014-06-19	20:14:07	Door2
182	out	2014-06-19	20:13:25	Door2
178	in	2014-06-19	20:11:58	Door1
177	in	2014-06-19	20:11:58	Door1
176	in	2014-06-19	20:11:58	Door1
175	in	2014-06-19	20:11:58	Door1

a)

attendanceid	inout	date	time	door
290	out	2014-06-19	20:24:42	Door2
289	in	2014-06-19	20:24:04	Door1
288	out	2014-06-19	20:23:26	Door1
287	in	2014-06-19	20:22:46	Door2
286	out	2014-06-19	20:22:05	Door2
285	in	2014-06-19	20:20:58	Door1
284	out	2014-06-19	20:20:15	Door1
283	in	2014-06-19	20:19:20	Door2
282	out	2014-06-19	20:18:39	Door2
281	in	2014-06-19	20:17:59	Door1
280	out	2014-06-19	20:17:21	Door1
279	in	2014-06-19	20:16:46	Door2
278	out	2014-06-19	20:16:05	Door2
277	in	2014-06-19	20:15:28	Door1
276	out	2014-06-19	20:14:48	Door1
275	in	2014-06-19	20:14:13	Door2
274	out	2014-06-19	20:13:40	Door2
273	in	2014-06-19	20:12:20	Door1
272	out	2014-06-19	20:11:29	Door1
271	in	2014-06-19	20:10:40	Door2
270	out	2014-06-19	20:09:46	Door2
269	in	2014-06-19	20:09:19	Door1

b)

attendanceid	inout	date	time	door
218	out	2014-06-19	20:24:23	Door2
217	in	2014-06-19	20:23:41	Door1
216	out	2014-06-19	20:23:04	Door1
215	in	2014-06-19	20:22:20	Door2
209	out	2014-06-19	20:18:13	Door2
201	in	2014-06-19	20:17:31	Door1
199	out	2014-06-19	20:16:58	Door1
197	in	2014-06-19	20:16:22	Door2
196	out	2014-06-19	20:15:40	Door2
195	in	2014-06-19	20:16:22	Door2
194	out	2014-06-19	20:15:40	Door2
191	in	2014-06-19	20:15:07	Door1
181	out	2014-06-19	20:14:25	Door1
180	in	2014-06-19	20:13:50	Door2
179	out	2014-06-19	20:13:10	Door2
174	in	2014-06-19	20:11:55	Door1
173	out	2014-06-19	20:11:07	Door1
172	in	2014-06-19	20:10:02	Door2
170	out	2014-06-19	20:09:22	Door2
169	in	2014-06-19	20:08:52	Door1

c)

Figure 5.4: Attendances registered on the server's database during the corridor test. (a) Samsung Galaxy S, (b) Huawei G300, (c) Samsung Tab2.

During the test, the Huawei G300 smartphone was the only one detecting all the movements across virtual doors. Since Figure 5.4-b represents Huawei's G300 registered attendances, it is also a representation of all the performed movements across those doors. The same figure (5.4-b) has represented all attendances missed by the Samsung Tablet (blue) and by the Samsung Galaxy S smartphone (orange).

The Samsung Galaxy S smartphone (Figure 5.4-a) didn't detect the first entrance movement at door 1 and at door 2. To solve this issue, the *Minimum Power* needed to be changed to a lower value to be able to start samples acquisition process at lower RSSIs. This was also caused because devices were using configurations established to detect virtual doors composed by APs of version 1.11 and, because the second virtual door was created using APs with version 2.1, there were some differences in terms of power transmission (version 2.1 APs transmit at lower power - Figure 5.5). Hence, devices needed to be reconfigured to be able to also detect virtual door number two. After that moment, all the movements were correctly detected by the smartphone.

A new situation has occurred during the tests with Samsung Galaxy Tab 2. Figure 5.4-b shows, in blue, four attendances that weren't detected by the tablet. These failures occurred because the wireless adapter has blocked. This issue was detected sometimes before this test, but it occurs due to some application's external problem that doesn't allow the application to perform scans. To solve this issue, the wireless adapter must be manually switched off and on again. This represents a problem to an application like this once it needs to be continuously performing scans in the background. During all the tests, this issue was only detected once.

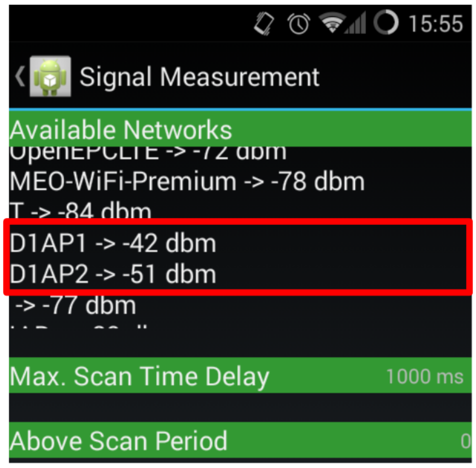


Figure 5.5: RSSI values of two side-by-side APs of the same model but of different versions (D1AP1 was version 1.11, D1AP2 was version 2.1)

Attendances marked in red were sent to the server more than once. They don't represent an error in the algorithm that detects attendances, and this occurred just for two of the devices, the Samsung Galaxy S and the tablet.

Like explained in section 4.2.7, the process of sending attendances to the server is acknowledgment (ACK)-based and this issue occurs when the ACK message is not received by the smartphone/tablet. The explanation is simple: during the movement along the corridors, when the device detected that Internet was available, a message containing all the attendances registered and not sent, is sent to the server. The fact of being ACK-based, requires the application to receive a message, sent by the server, indicating that the message containing all the data was received and stored.

During this test, the smartphone (and the tablet) detected that Internet was available through some AP installed in the building. In this situation, pendent attendances were sent to the server. Nonetheless, before receiving the *success* message sent by the server, the device lost access to the Internet due to the fact of being moving along the corridors. Once the *success* message was not received, attendances sent by the devices were not marked as sent. When they reacquired access to the Internet, those attendances were sent again to the web server causing them to be repeated because it does not validate attendances to see if they are repeated or not.

The reason why the Huawei G300 didn't verify this problem was because it didn't have access to the Internet through any AP of the building since no wireless connection was configured before that moment. Attendances were sent to the server only after the tests were finished and after configuration of an Internet connection in the smartphone. That's the reason why the *attendanceid* column of the Huawei G300 (Figure **??** has greater values than other devices because the last attendances to be sent to the server were the Huaweis' attendances.

During this test, 22 passages through two different virtual doors were performed and three different devices were used to detect them. The Huawei device detected 100% of the passages while Samsung devices detected 18 passages each, the smartphone because it needed some reajustments on the configurations, the tablet because the wireless adapter blocked.

The test proved that a virtual door composed by two APs just separated by a five meter distance is a very efficient way to install the system when there is no possibility to install the

APs with an attenuating material between them.

5.5.2 Virtual door installed at the entrance door of IT Lab211

This test was made to understand the behavior of the RPAapp application when virtual doors are installed in a room inside a building. To test it, the virtual door was installed in IT's Lab211 like shown in Figure 5.6. APs were separated by a plywood wall. The room only has one entrance door and that door can be reached from two different sides like represented in Figure 5.6 (green arrows).

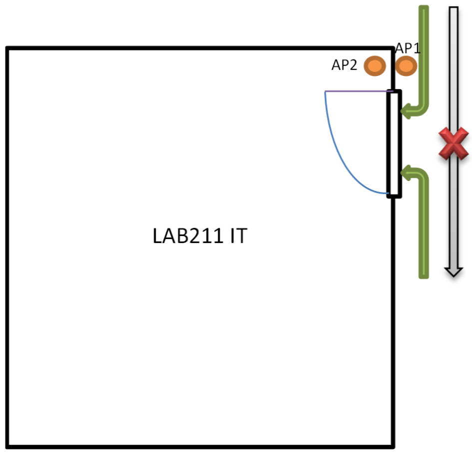


Figure 5.6: IT's Lab211 plan showing where APs were installed.

RPAapp's *Settings* configurations are shown in table 5.3. These are the final values used once they needed to be readjusted during the execution of the test ir order to achieve better results.

	Samsung Galaxy S	Huawei G300	Samsung Tab 2
Minimum Power (dBm)	-52	-50	-45
Increase search freq.(dBm)	-75	-75	-70
Search Frequency (s)	2	2	2
Minimum Search Freq (s)	5	5	5
Waiting time (s)	1	1	1
Time to wait after check (s)	15	20	20
Max Time to check (s)	30	40	30

Table 5.3: Final configurations of RPAapp's *Settings* after running the test in IT Lab211.

Figure 5.7 shows all attendances registered during this test by all the devices. Analyzing this data and knowing that the Huawei G300 registered all the movements across the virtual door, it can be concluded that the Samsung Tab2 failed to detect two movements (orange) and the Samsung Galaxy S failed to detect three movements (blue).

The first failed detection (failed by the Samsung Tablet and the Galaxy S smartphone) occurred because *Minimum Power* parameter defined was to high. Because of this issue,

attendanceid	inout	date	time	door
78	in	2014-06-17	16:50:20	Door2
76	out	2014-06-17	16:49:37	Door2
74	in	2014-06-17	16:48:48	Door2
73	out	2014-06-17	16:48:09	Door2
68	in	2014-06-17	16:47:26	Door2
64	out	2014-06-17	16:46:44	Door2
60	in	2014-06-17	16:40:24	Door2
59	out	2014-06-17	16:16:58	Door2
51	in	2014-06-17	16:12:03	Door2
49	out	2014-06-17	16:11:22	Door2
48	in	2014-06-17	15:59:31	Door2
38	out	2014-06-17	15:58:26	Door2
37	in	2014-06-17	15:57:02	Door2
35	out	2014-06-17	15:56:06	Door2
34	in	2014-06-17	15:51:38	Door2
32	out	2014-06-17	15:50:54	Door2
30	in	2014-06-17	15:49:42	Door2
28	out	2014-06-17	15:48:45	Door2
26	in	2014-06-17	15:46:39	Door2
24	out	2014-06-17	15:45:50	Door2
22	in	2014-06-17	15:44:06	Door2
17	out	2014-06-17	15:43:08	Door2
16	in	2014-06-17	15:41:41	Door2
14	out	2014-06-17	15:39:46	Door2
10	in	2014-06-17	15:38:14	Door2
9	out	2014-06-17	15:37:33	Door2
8	in	2014-06-17	15:35:58	Door2
7	out	2014-06-17	15:34:26	Door2

a)

attendanceid	inout	date	time	door
77	in	2014-06-17	16:50:08	Door1
75	out	2014-06-17	16:49:18	Door1
72	in	2014-06-17	16:48:37	Door1
69	out	2014-06-17	16:48:02	Door1
67	in	2014-06-17	16:47:14	Door1
63	out	2014-06-17	16:46:32	Door1
62	in	2014-06-17	16:41:10	Door1
53	out	2014-06-17	16:16:51	Door1
52	in	2014-06-17	16:11:53	Door1
50	out	2014-06-17	16:11:14	Door1
47	in	2014-06-17	15:59:20	Door1
36	out	2014-06-17	15:55:54	Door1
33	in	2014-06-17	15:51:25	Door1
31	out	2014-06-17	15:50:43	Door1
29	in	2014-06-17	15:49:27	Door1
27	out	2014-06-17	15:48:33	Door1
25	in	2014-06-17	15:46:27	Door1
23	out	2014-06-17	15:45:36	Door1
21	in	2014-06-17	15:43:51	Door1
18	out	2014-06-17	15:43:00	Door1
15	in	2014-06-17	15:41:26	Door1
13	out	2014-06-17	15:39:19	Door1
12	in	2014-06-17	15:38:13	Door1
5	out	2014-06-17	15:34:17	Door1

b)

attendanceid	inout	date	time	door
80	in	2014-06-17	16:50:09	Door2
79	out	2014-06-17	16:49:15	Door2
71	in	2014-06-17	16:48:48	Door2
70	out	2014-06-17	16:48:10	Door2
66	in	2014-06-17	16:47:20	Door2
65	out	2014-06-17	16:46:39	Door2
61	in	2014-06-17	16:40:25	Door2
57	out	2014-06-17	16:17:04	Door2
56	in	2014-06-17	16:12:04	Door2
55	out	2014-06-17	16:11:20	Door2
54	in	2014-06-17	15:59:25	Door2
46	out	2014-06-17	15:58:12	Door2
45	in	2014-06-17	15:56:55	Door2
44	out	2014-06-17	15:56:04	Door2
43	in	2014-06-17	15:51:30	Door2
42	out	2014-06-17	15:50:48	Door2
41	in	2014-06-17	15:46:32	Door2
40	out	2014-06-17	15:45:45	Door2
39	in	2014-06-17	15:44:04	Door2
19	out	2014-06-17	15:43:06	Door2
11	in	2014-06-17	15:38:17	Door2
4	out	2014-06-17	15:34:25	Door2

c)

Figure 5.7: Attendances registered on the server's database by each of the devices during the IT Lab211 test. Huawei G300 (a), Samsung Tab2 (b), Samsung Galaxy S (c).

during the movement through the virtual door, devices never detected RSSIs greater than *Minimum Power*, causing the samples acquisition process to never start.

According to the log window of the application, the other attendance missing from Samsung Tablet occurred because the tablet didn't finish the acquisition process during the *Max Time to Check* interval. Nonetheless, both smartphones detected the movement within the *Max Time to Check* and this can be justified by the simple fact that the tablet has a powerful wireless adapter, i.e., when placing both smartphones and the tablet at the exactly same place, the Samsung tablet detects greater RSSIs. This means that, although smartphones were far away enough to finish the *Samples Aquisition* process, the tablet wasn't away enough so, when the counter reached the *Max Time to Check*, the movement was discarded.

Also according to the application's log window, the other two failed detections from the Samsung Galaxy S, occurred because the samples acquisition process never started. There are only two possibilities for this to happen: the application was not running or the RSSIs detected by the smartphone weren't never high enough during the movement to start the samples acquisition process. Once the application was running, every time this happened, the device was calibrated configuring a new value to the *Minimum Power*.

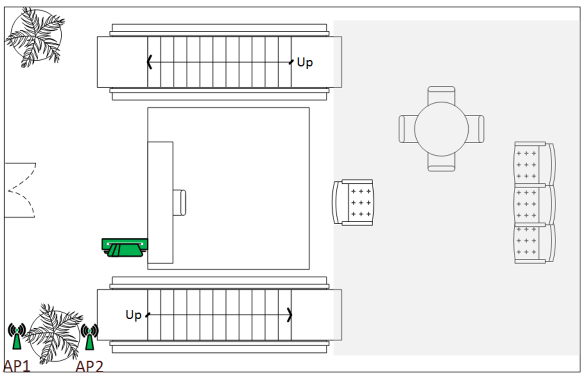
Attendances marked within the red rectangle must also be emphasized once they do not correspond to a movement through the virtual door, but to a movement along the corridor next to the laboratory (gray arrow, Figure 5.6). This represents a failure on the system and the proof is that it was detected by all the devices at the same time. It happened because, when getting close to the virtual door, the samples acquisition process started normally because the AP1 RSSI is greater than *Minimum Power*. Then, even if the user doesn't enter the room, the application continues to acquire samples till the moment the AP1 RSSI is lower than *Minimum Power*. The analysis of these samples returned then wrong entrance/exit movement indications.

It may be a difficult problem to solve because of the wireless waves propagation and reflection through the space, which means that it will probably persist even if directional antennas are used. A possible solution may be a change to the decision algorithm. Force the RSSI from the AP inside the room to be greater or equal to the RSSI of the AP placed outside, may be a good solution to change these wrong detections, but it may cause other problems. Tests must be performed to confirm that it can be a solution.

During this test, 28 passages were detected but only 26 were made through the virtual door. Two of passages were just a movement through the corridor and not through the door. In total, 78 attendances should have been registered during this test but only 68 were. Once the application can't register a *Check In* without registering a *Check Out* first (and vice-versa), every time a detection fails, the next detection will possibly be detected but it will be excluded. Thus, of the 78 attendances that should be registered, 5 failed to register, which means that 93% of the passages were correctly registered.

5.5.3 Virtual door installed at the entrance of the IT building

The main difference between this test and the tests described before, is the fact that it allows to compare attendances registered by the RPAapp application with attendances registered by the RFID attendance system installed in the building. To achieve this, at the same time smartphones were detecting the installed virtual door, the RFID card was also used to register attendances. At the end of the test, it was expected to have each attendance registered by all the smartphones/tablets and by the RFID system.



(a) Virtual door and RFID card reader position at the entrance of the building.

Marcações efectuadas

Desde: 18-06-2014 Até: 18-06-2014 Filtrar

Data	Hora	ID Utilizado
18-06-2014	10:27	000040652617
18-06-2014	12:24	000040652617
18-06-2014	13:54	000040652617
18-06-2014	19:29	000040652617
18-06-2014	22:20	000040652617
18-06-2014	22:42	000040652617
18-06-2014	22:47	000040652617
18-06-2014	22:53	000040652617
18-06-2014	22:55	000040652617
18-06-2014	23:00	000040652617
18-06-2014	23:03	000040652617
18-06-2014	23:09	000040652617
18-06-2014	23:17	000040652617
18-06-2014	23:29	000040652617
18-06-2014	23:35	000040652617
18-06-2014	23:39	000040652617
18-06-2014	23:43	000040652617
18-06-2014	23:45	000040652617
18-06-2014	23:47	000040652617
18-06-2014	23:50	000040652617

(b) RFID attendances registered.

Figure 5.8: IT's entrance plan showing the position of the APs of the virtual door (a) and the attendances registered by the RFID system (b).

Attendances registered using the RFID card are shown in Figure 5.8b. These attendances are available through the website provided by the IT's service[39]. One characteristic that this service does not provide is the capacity to provide information about the direction of the user (entering/exiting) when he/she swipes the card. The test occurred between 22:50 and 23:55 on 18-June and they were registered fourteen attendances by the RFID card.

attendanceid	inout	date	time	door
137	in	2014-06-18	23:55:19	Door2
135	out	2014-06-18	23:53:22	Door2
134	in	2014-06-18	23:51:52	Door2
133	out	2014-06-18	23:47:29	Door2
130	in	2014-06-18	23:43:24	Door2
129	in	2014-06-18	23:43:24	Door2
128	out	2014-06-18	23:37:54	Door2
123	in	2014-06-18	23:25:57	Door2
122	out	2014-06-18	23:17:17	Door2
113	in	2014-06-18	23:10:45	Door2
112	out	2014-06-18	23:08:17	Door2
111	in	2014-06-18	23:02:18	Door2
110	in	2014-06-18	23:02:18	Door2
109	out	2014-06-18	23:00:16	Door2
104	in	2014-06-18	22:55:23	Door2
103	out	2014-06-18	22:50:48	Door2

a)

attendanceid	inout	date	time	door
141	in	2014-06-18	23:55:28	Door2
140	out	2014-06-18	23:53:30	Door2
139	in	2014-06-18	23:52:01	Door2
138	out	2014-06-18	23:47:29	Door2
132	in	2014-06-18	23:43:35	Door2
131	out	2014-06-18	23:37:50	Door2
125	in	2014-06-18	23:26:03	Door2
124	out	2014-06-18	23:17:36	Door2
121	in	2014-06-18	23:10:40	Door2
120	out	2014-06-18	23:08:08	Door2
117	in	2014-06-18	23:02:22	Door2
116	out	2014-06-18	23:00:22	Door2
106	in	2014-06-18	22:55:18	Door2
105	out	2014-06-18	22:50:18	Door2

b)

attendanceid	inout	date	time	door
146	in	2014-06-18	23:54:59	Door1
145	out	2014-06-18	23:53:30	Door1
144	in	2014-06-18	23:51:37	Door1
143	out	2014-06-18	23:47:03	Door1
142	in	2014-06-18	23:43:02	Door1
136	out	2014-06-18	23:37:39	Door1
127	in	2014-06-18	23:25:52	Door1
126	out	2014-06-18	23:17:27	Door1
119	in	2014-06-18	23:10:32	Door1
118	out	2014-06-18	23:07:57	Door1
115	in	2014-06-18	23:02:07	Door1
114	out	2014-06-18	23:00:04	Door1
108	in	2014-06-18	22:54:00	Door1
107	out	2014-06-18	22:49:55	Door1

c)

Figure 5.9: Attendances registered on the server's database during the execution of the IT Entrance test. (a) Samsung Galaxy S, (b) Huawei G300, (c) Samsung Tab2

Figure 5.9 shows the attendances registered on the server's database during the test. The first passage through the virtual door was to leave the building at 10:50pm. Comparing the times registered by the RPAapp and RFID card, there is a difference of 8 minutes between them. That happens because the system installed in the building has a delay of eight minutes.

The results obtained with this test were quite good since none of the devices failed to detect a movement through the virtual door installed like represented in Figure 5.8a.

All the devices had Internet access during the test. Nonetheless, only the Samsung Galaxy S sent two repeated attendances to the server's database. This situation was caused by the loss of the ACK message sent by the server to the device, like happened in the corridor test.

	Samsung Galaxy S	Huawei G300	Samsung Tab 2
Minimum Power (dBm)	-60	-60	-55
Increase search freq.(dBm)	-80	-80	-70
Search Frequency (s)	2	2	2
Minimum Search Freq (s)	5	5	5
Waiting time (s)	1	1	1
Time to wait after check (s)	60	60	60
Max Time to check (s)	40	40	40

Table 5.4: Configurations of RPAapp's *Settings* used during the tests at the entrance of IT.

For this test, devices were configured to start scanning for virtual doors earlier than in the other tests. The samples acquisition process was also configured to start earlier by decreasing the value of *Minimum Power*. By doing this, the scans started to be performed when far from the virtual door and, therefore, more samples were acquired. Hence, this required the *Max Time to check* to be greater and it required a larger zone in the range of the virtual door where persons could not stop, otherwise the RPAapp will be saving samples until the moment the *Max time to check* is reached, excluding the passage. In the *Future Work* section of the next chapter, it is introduced an idea to stop the need to be outside the virtual door area before *Max time to check* is reached.

Chapter 6

Conclusions and future work

6.1 Summary

In this chapter it is done an overview of the entire project developed and are presented the conclusions reached through the tests made. At the end of the chapter are also listed some ideas that can improve the project in the future.

6.2 Conclusions

Attendance control at the job site or at school is, today, more important than it was in the past and it will become even more important in the future because of the competitive environment that exist within the companies and even schools and universities, where good assiduity and attendance can make all the difference.

It is known that, when someone has attendance problems, if they are not controlled since the beginning, they can become more and more serious. For an employer, a teacher or even a children's parent, the ability to have all the attendances' information available through the smartphone/tablet with a connection to the Internet may be important to detect this problem earlier.

To prevent these problems from happening, in this dissertation it was proposed an attendance and punctuality system based on Android-based smartphones (or tablets) and virtual doors composed by two access points per virtual door. The system provides the ability to register attendances without using an RFID card, fingerprint scanners, etc., only the smartphone is necessary when the virtual doors are installed in the building where attendances must be registered. Being inexpensive, completely automatic and the unlikely event of buddy punching are some of the main advantages of the system.

To build the system, an Android mobile application (RPAapp) was developed to run in the background of the smartphone's operating system. Through this application, the user configures the virtual doors where the smartphone must register attendances (it can be more than one virtual door) and the necessary parameters (differs from one device to another) to allow the detection of the doors. After finished the configurations, the application is ready to start running in the OS's background performing wireless scans to detect the networks created by the APs of each virtual door. When a virtual door is detected the application runs the algorithm developed after an analysis to the behavior of the transmitted APs' radio signals. This algorithm allows to detect the direction of the movement (check in/out),the date, time and door where the event happened sending this information to the server when the smartphone detects that a connection to the Internet is available (through Wi-Fi or mobile network).

In section 5, some tests were performed to analyze the battery consumption of the mobile application and the behavior of the entire system (RPAapp, virtual doors and server all working together).

The battery consumption is always a sensitive question and that was the main reason to execute this test. The results acceptable when considering one full battery charge per day. For daily use, the RPAapp will probably need the smartphone to be charged every day.

The test also demonstrated that, this application can run in the background of the operating system for several hours. The Huawei device only spent 44% of the battery during the 16 hours it was not charging and with the RPAapp running during more than nine hours. It is important to notice that this device was equipped with a 1500mAh which is the basic capacity for smartphones.

The test using the Samsung tablet also returned good results with the application consuming just 17% of the battery consumed till that moment.

The Samsung Galaxy S smartphone had the worst results but that was mainly due to the age of the battery (four years). Comparing to daily usage experience of the device (where it is always with the wireless adapter switched on), the results are considered to be good once the battery lasted around one hour and a half less than when RPAapp is not running. Once the usage is not always the same, they will be needed more tests to make good conclusions about this.

An important information obtained through the tests are the excessive number of scans after several hours running. Knowing that the operating system also scans for networks when the wireless adapter is switched on, these numbers become even greater. There are two ways to reduce this problem and they will be presented next, in the *Future work* section.

It was also concluded that not all the devices can successfully run the application because of wireless adapter's hardware limitations. A test executed using a Samsung Galaxy S 2 Plus returned nineteen failed scans during just one minute and a half. As a consequence, when trying to register attendances using this device, most of the attendances were not successfully registered. The *Signal Measurement* tool gives important information to conclude about the possibility to use a certain smartphone model with this system.

The first test to the entire system was the corridor test. This test returned good results once 60 of 66 attendances were successfully detected. Two of the failures were due to *Settings* configurations bad adjustments and the other four due to a problem that sometimes may occur with the wireless adapter (blocking situations).

The test at the entrance of the lab211 was performed to test the usage capabilities of the system when installed in an interior division of the building. The results were also good (68 of 78 attendances successfully detected). Nonetheless, a problem may occur when used in these conditions once, two of the attendances shouldn't have been registered because the movement was not performed across the virtual door, just near to it. To use the system inside the building to control attendances in a specific room, some adjustments will need to be done and it should be tested the usage of directional antennas instead of the traditional omni-directional antennas that equip the APs.

The last test was also a test to the system. The virtual door was installed at the entrance of the IT building. The results couldn't be better once none of the attendances failed to be detected by the devices.

During these tests, some attendances were submitted to the server more than once and, because the server doesn't validate the attendances to find out if they are repeated or not, those attendances were repeatedly stored in the database. This happens when the smartphone looses the connection to the Internet before the reception of the ACK message informing that all attendances were successfully saved. Next, in *Future Work* seccion, it is introduced a solution to solve this issue.

The tests also proved that, when more than one virtual door is needed, the APs used in all the virtual doors must be of the same model, otherwise, failed attendances situations may occur due to the different transmission power between them.

In general, the system proved to be efficient and that can be applied in several different situations. Nonetheless, especially when the idea is to use it to control attendances at some rooms inside a building (school classes for example), it needs to be optimized to reduce the probability of failures. The next section introduces some of those aspects that can be optimized in the future in order to achieve better results.

6.3 Future Work

At the end of this project, main goals were reached: the system detects and registers entrances and exits using just radio signals sent by the APs that compose the virtual door. Nonetheless, according to the conclusions described above, some improvements can be made to the project:

6.3.1 Battery consumption improvements

- Since battery lifetime of the smartphone is an important factor, the introduction of Location based services (LBS) to detect the smartphone position can allow the mobile application to start scan only when the user is near the zone where virtual doors are installed. There are several strategies less abrasive to smartphone's battery like obtain position through cellphone network cells for example.

- At this moment, the RPAapp needs the wireless adapter to be switched on in order to scan for networks. Like referred in the conclusions section, this can lead to unwanted connections to some APs that provides Internet connection. Newest versions of Android (4.3+) have the capacity to scan for networks without needing the wireless adapter to be fully activated: it perform scans but without connecting to any networks.

- To avoid unnecessary scans, RPAapp could search for virtual doors only when the smartphone's accelerometer is detecting movement, otherwise it won't scan. This could lead to a significant decrease of the number of scans and it can be also important for those situations where the virtual door is installed in a school classroom, like the IT's Lab211.

6.3.2 RPAapp performance and functionality improvements

- If installed in schools, an interesting feature could be the possibility to automatically send a notification to children's parents notifying about the time when they arrive or left the school.

- Download from the server the door's configurations and settings instead of be configured by each user.
- Change the algorithm to allow the *Minimum Power* parameter to be exclusive to each virtual door. The different environment conditions where virtual doors are installed can lead to the necessity of different *Minimum Power* values.
- To avoid replicated attendances in the database, the server should validate each attendance sent by the smartphone. A simple and effective way to achieve this, is to create a sequence number (in the smartphone-side) that is incremented when an attendance is registered. This number can then be used by the server to exclude replicated attendances.

Bibliography

[1] (2014, April 7th) Timeclock solution. [Online]. Available: http://timeclockplus.com/Default.aspx

[2] (2014, 23 June) Samsung galaxy s i9000. [Online]. Available: http://www.samsung.com/pt/consumer/mobile-phone/smartphones/android/GT-I9000HKDTPH-features

[3] (2014, 23 June) Samsung galaxy tab 2. [Online]. Available: http://www.samsung.com/pt/support/model/GT-P3110TSETPH

[4] (2014, 23 June) Tp-link tl-wr1043ndv2.1. [Online]. Available: http://www.tp-link.com/en/support/download/?model=TL-WR1043ND&version=V2

[5] P. Sweeney, "Rfid for dummies," in *Wiley Publishing, Inc., Indiana, 1st Edition*, 2005, pp. 1–21.

[6] (2014, March 15th) The wfc group. [Online]. Available: http://www.thewfcgroup.com/

[7] (2014, March 16th) Easy clocking. [Online]. Available: www.easyclocking.com

[8] K. N. Anil K. Jain, Arun A. Ross, "Introduction to biometrics," in *Springer, New York*, 2011, ch. 1,2,3,4,7.

[9] N. Science and T. C. (NSTC), "Hand geometry," 2006.

[10] R. W. S. Lawrence R. Rabiner, "Introduction to digital speech processing," in *Foundations and Trends in Signal Processing*, 2007.

[11] R. Chellappa, C. Wilson, and S. Sirohey, "Human and machine recognition of faces: a survey," *Proceedings of the IEEE*, vol. 83, no. 5, pp. 705–741, May 1995.

[12] W. Zhao, R. Chellappa, P. J. Phillips, and A. Rosenfeld, "Face recognition: A literature survey," *ACM Comput. Surv.*, vol. 35, no. 4, pp. 399–458, Dec. 2003. [Online]. Available: http://doi.acm.org/10.1145/954339.954342

[13] (2014, March 23th) Time well scheduled. [Online]. Available: http://timewellscheduled.com

[14] G. Williams, "Iris recognition technology," *Aerospace and Electronic Systems Magazine, IEEE*, vol. 12, no. 4, pp. 23–29, Apr 1997.

[15] (2014, April 7th) Timesheet mobile. [Online]. Available: http://timesheetmobile.com/index.html

[16] (2014, April 4th) Bodet - time for all. [Online]. Available: http://www.bodet.co.uk/time-attendance/clocking-in-systems/smartphone-clocking.html

[17] (2014, April 5th) Exacttime mobile. [Online]. Available: http://www.exaktime.com/mobile-time-clock

[18] G. M. Shraddha S. Chawhan, Mangesh P. Girhale, "Mobile phone based attendance system," *IOSR Journal of Computer Engineering (IOSR-JCE)*, vol. Volume 10.

[19] F. N. Ivanilson Ganga Francisco, Boniface Kabaso, "Developing an automatic attendance register system for cput," Master's thesis, Cape Peninsula University of Technology.

[20] "Cell phone attendance system based on wifi signals," Dec. 4 2013, cN Patent App. CN 201,310,371,936. [Online]. Available: https://www.google.com/patents/CN103426208A?cl=en

[21] (2014, May 22) Bbcnews. [Online]. Available: http://news.bbc.co.uk/2/hi/uk_news/2963619.stm

[22] (2014, May 22) Motorola solutions history. [Online]. Available: http://www.motorolasolutions.com/US-EN/About/Company+Overview/History/Timeline

[23] E. Forum, "Engineers forum magazine," May 22 2014. [Online]. Available: http://www.ef.org.vt.edu/2013/11/the-evolution-of-the-mobile-phone.html

[24] (2014, May 22) Grupomarktest - 3.5 milhões de utilizadores em portugal. [Online]. Available: http://www.marktest.com/wap/a/n/id~1bfc.aspx

[25] (2014, May 22) Jornal público - smartphones em portugal ultrapassaram telemóveis tradicionais. [Online]. Available: http://www.publico.pt/tecnologia/noticia/smartphones-em-portugal-ultrapassaram-telemoveis-tradicionais-1624400#/0

[26] (2014, May 23) Apdc - mercado acima dos 2 mil milhões de smartphones. [Online]. Available: http://www.apdc.pt/legacy/Artigo.aspx?channel_id=3430D560-04A5-432A-B893-3224E5CEFBBC&content_id=33E4908F-975F-4C07-B7B0-0672894906FF&lang=pt

[27] M. B. D. Felker, "for dummmies," in *Android Application Development*, 2013.

[28] D. C. Iggy Krajci, "An introduction to optimizing for intel architecture," in *Android on x86*, 2013.

[29] M. N. Marko Gargenta, "Develop mobile apps using java and eclipse," in *Learning Android*, 2013, pp. 1–33.

[30] M. Wolfson, "Android developer tools essentials," in *Android Developer Tools Essentials*, 2013, p. 2.

[31] (2014, May 24) Platform versions. [Online]. Available: https://developer.android.com/about/dashboards/index.html?utm_source=ausdroid.net#Platform

[32] M. Gast, in *Network Know-How*.

[33] (2014, 30 May) Free web host. [Online]. Available: http://www.000webhost.com/

[34] (2014, 9 June) Android developers - services. [Online]. Available: http://developer.android.com/guide/components/services.html

[35] (2014, 13 June) Android developers - broadcast receivers. [Online]. Available: http://developer.android.com/reference/android/content/BroadcastReceiver.html#q=broadcastreceiver

[36] (2014, 1 July) Android developer tools. [Online]. Available: http://developer.android.com/sdk/index.html

[37] (2014, 23 June) Tp-link tl-wr1043ndv1.11. [Online]. Available: http://www.tp-link.com/en/support/download/?model=TL-WR1043ND&version=V1

[38] (2014, 23 June) Huawei ascend g300. [Online]. Available: http://consumer.huawei.com/en/mobile-phones/features/u8815-en.htm

[39] (2014, 21 June) Webtime. [Online]. Available: https://www.intra.av.it.pt/webtime

[40] U. M. Chaskar and M. Sutaone, "A novel approach for iris recognition," in *Computer Technology and Development (ICCTD), 2010 2nd International Conference on*, Nov 2010, pp. 495–500.

[41] M. Gast, in *802.11 Wireless Networks*, 2005.